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CRUDE GLYCEROL GLUCOSIDE ESTERS FROM COTTONSEED OIL: PRELIMINARY COSTS AND SPECIFICATIONS

An Engineering Prospectus

July 6, 1976

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Acknowledgment

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CONTENTS

COST INDEXES

The following information on cost indexes is provided for the reader's convenience in updating costs to suit his or her particular situation.

Equipment costs are with few exceptions those in effect in November 1975 (4th Quarter 1975) when some relevant cost indexes were as follows:

Marshall and Swift equipment cost index
(1926 = 100)
process industries, average.................... 450.6

Chemical Engineering (CE) plant cost index
(1957-59 = 100)..................................... 185.5
equipment, machinery, supports................ 198.2
construction labor........................... 171.2
buildings....................................... 179.4
engineering and supervision.................. 143.7

The building cost cited was in effect in February 1976 (1st Quarter 1976) when some relevant cost indexes were as follows:

Chemical Engineering (CE plant cost index
(1957-59 = 100)..................................... 187.6
equipment, machinery, supports................ 200.3
construction labor........................... 171.7
buildings....................................... 183.0
engineering and supervision.................. 148.5

ENR Building Cost Index (1967 = 100)................ 203

ENR Construction Cost Index (1967 = 100)............ 215

Austin Co. Building Cost Index (1967 = 100)......... 193

Boeckh Building Cost Index (1967 = 100)............. 200

Chemical costs, utilities costs, labor costs and other operating costs were calculated from prices, schedules, and rates applicable in March 1976 (1st Quarter 1976).

Results of Cost Analysis

A. Plant Description

Plant Capacity: One 12-ton batch of crude glycerol glucoside esters per 8-hour shift, or three 12-ton batches daily.

Arrangement: A grass-roots plant (complete, erected on a new site).

Scope of Operations: A cornstarch receiving, storage, and drying system; a 5,500-gallon reactor with auxiliary process equipment for producing crude esters; raw materials and product storage facilities; and service facilities.

Schedule of Operations: Twenty 8-hour shifts monthly.

Production Rate: Twenty 12-ton batches monthly, or 240 tons per month. (One 12-ton batch per day for 20 days, or equivalent.)

Process: Acid catalyzed transglycosylation of starch with a sizeable excess of glycerol; followed by neutralization of acid catalyst with sodium carbonate, and soap-catalyzed inter-esterification of glycerol glucosides with partially hydrogenated cottonseed oil, with simultaneous recovery of unreacted glycerol by distillation.

Product: Crude glycerol glucoside esters for use as a food emulsifier.

Utilities:

Electricity: 768.7 kw-hr/12-ton batch;
210.6 kw. peak demand.

Cooling water: 4.2 M gals. makeup/12-ton batch at a rate of 12 g.p.m.; 311.6 g.p.m. to be chilled from 120°F. to 85°F.

Steam: 250 p.s.i.g.
13 M lbs./12-ton batch;
max. rate of 7.7 M lbs./hr.

Natural gas: 22.6 M s.c.f./12-ton batch;
max. rate of 21.7 M s.c.f./hr.

B. Costs

Fixed Capital Investment: Refer to "Summary" on p. 65.)

Entire Plant	$ 2.5 million
Starch System Only	$815,200

Manufacturing Costs and General Expenses: (Refer to "Summary on p. 79.)

	If crude esters are the only product manufactured (no sharing of equipment with other products); equivalent to operating 1 shift daily	If other products are manufactured when not producing esters (sharing of equipment with other products); equivalent to operating 3 shifts daily
	cents/pound crude esters	
Esters produced entirely from fresh raw materials		
In new or partly depreciated plant	44.41	37.31
In depreciated plant	42.30	36.61
Esters produced from fresh raw materials and recovered glycerol glucosides from previous batch		
In new or partly depreciated plant	40.80	33.36
In depreciated plant	38.59	32.62

Profitability: (Refer to "Summary" on p. 101; and to Table VI for complete range of selling prices.)

	If crude esters are the only product manufactured (no sharing of equipment with other products); equivalent to operating 1 shift daily		If other products are manufactured when not producing esters (sharing of equipment with other products); equivalent to operating 3 shifts daily	
Selling price, cts./lb.	51.00	73.21	41.00	51.10
Cost, cts./lb.	44.41	44.41	37.31	37.31
Profit before taxes, cts./lb.	6.59	28.80	3.69	13.79
Annual profit, M dols.				
Before taxes	378.7	1,655.3	212.1	792.5
After taxes	210.4	874.2	123.8	425.6
Annual rate of return on investment, %				
Before taxes	11.44	50.00	13.38	50.00
After taxes	6.36	26.41	7.81	26.85
Payout period, yrs.				
Before taxes	5.04	1.40	3.31	0.99
After taxes	7.68	2.50	5.13	1.78

Other: Fixed capital investment, manufacturing costs and general expenses, and profitability for a smaller plant producing sixty 4-ton batches of crude esters monthly, are reported in "6. Fixed Capital Investment," "7. Manufacturing Costs and General Expenses," and "8. Profitability," on pages 65, 79, and 104, respectively. Fixed capital investment for the smaller plant is about three fourths that of the 12-ton batch plant; manufacturing costs and general expenses are higher at the 240 ton/month ester production level than for the 12-ton batch plant; and little or no potential exists for reducing manufacturing costs and general expenses by expanding esters production above the 240 ton/month level or by sharing equipment with other products as in the case of the 12-ton batch plant, because the smaller plant would already be operating close to or at capacity producing crude esters alone.

1. INTRODUCTION

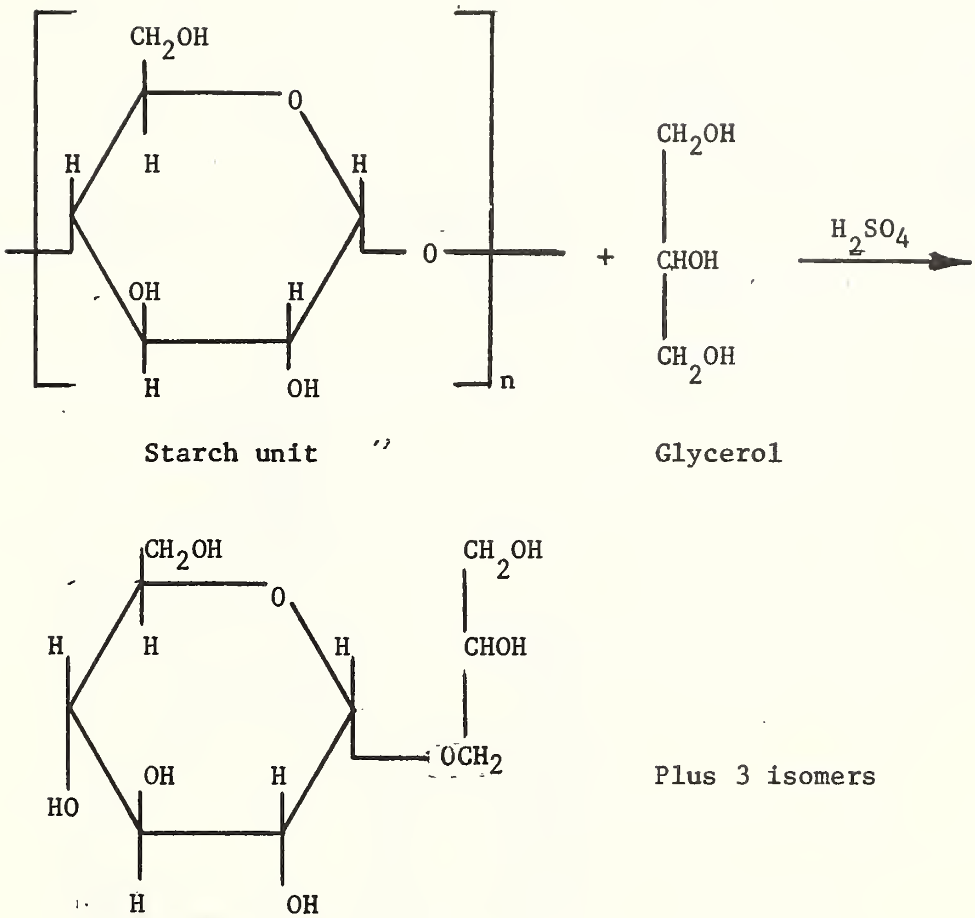
Purpose. This prospectus is intended to provide a basis for industry consideration of the batch process for producing crude glycerol glucoside esters, which has been developed by scientists of the Southern Regional Research Center as a means of producing highly effective, inexpensive food emulsifiers. It provides a cost analysis of a hypothetical plant of preliminary design for producing 12-ton batches of crude esters, which is equivalent to 10 tons of purified esters (83.5 percent yield). Included are a description of the process, material balances, equipment and plant specifications and arrangements, fixed capital investment, raw materials and utilities requirements, manufacturing costs, general expenses, and profitability.

Background. Fatty acid esters of the glycerol glycosides occur naturally (1-3)[a], and a patent application has been filed on the use of certain glycoside esters as emulsifiers in foods (4).

A number of glycerol glycoside ester products have been prepared and examined by Reuben O. Feuge, John L. White, Sr., and Mona Brown of the Southern Regional Research Center (SRRC). These scientists have reported on the preparation of fatty acid esters of polyol glucosides (5); surface activity of glycerol glycoside palmitates (6); properties of some glycerol glucoside palmitates (7); surface activity of glycerol glucoside esters (8); and composition of glycerol glucoside esters prepared by transglycosylation and interesterification (9). The transglycosylation procedure used in glycerol glucoside esters research at SRRC has been essentially that of Otey, et al. (10,11). However, in the course of his work, Feuge devised a single-step, solvent-free interesterification process for producing fatty acid esters of glycosides, which esters contain relatively large proportions of monoesters and relatively large numbers of free hydroxyl groups per molecule; of such composition to be useful as surface active agents. His process consists of interesterifying glycosides of glycerol and the various glycols with certain relatively hydrophilic esters of 6 to 24 carbon atom fatty acids in the presence of certain alkali metal soaps which function as catalysts. The mixed reactants are heated to the range of 150°C. to 220°C., and interesterification occurs at that temperature, preferably under vacuum.

a/ (References are listed on p. 10 .)

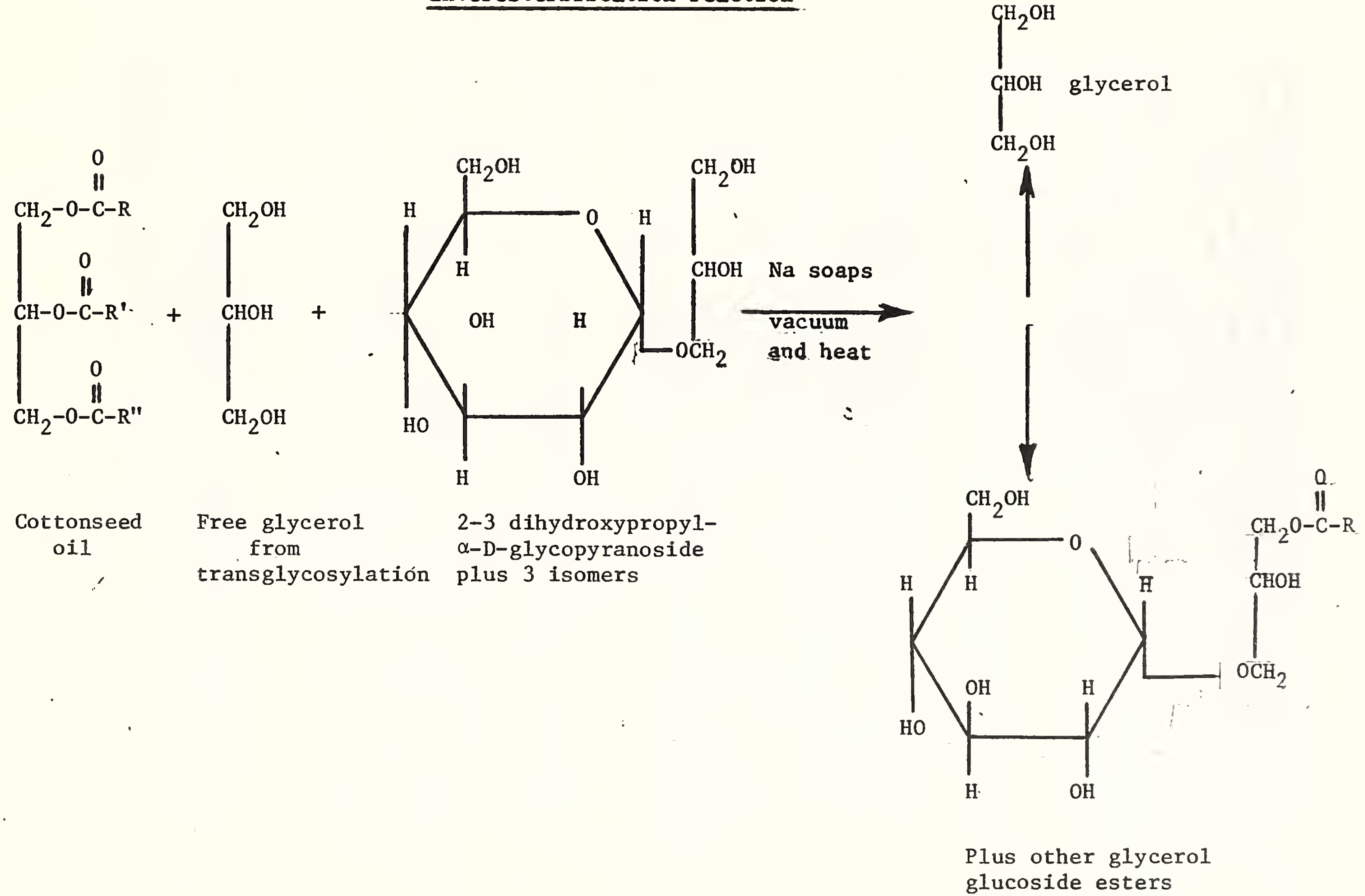
Transglycosylation Reaction



Plus 3 isomers

2-3 dihydroxypropyl-
α-D-glycopyranoside

Interesterification reaction



Research work on glycerol glucoside esters at the SRRC was done in the laboratory in 5-liter and 12-liter 3-neck flasks. The center neck of the flask accommodated a mechanical stirrer, and nitrogen was introduced through a shortened stripping tube located in one side neck. The glycerol recovery system consisted of a series of apparatus leading from the reaction flask, namely, a glass condenser, a one-liter round bottom flask serving as the glycerol receiver, two dry ice condensate traps in series to insure that glycerol would not reach the vacuum pump, and the vacuum pump.

The hypothetical plant of the cost analysis was designed on the basis of laboratory data obtained using this equipment.

Crude glycerol glucoside ester product. (a) Composition. The crude product of the cost analysis (made using 3 moles of glycerol per AGU of cornstarch) consists mostly of glycerol glucoside esters (purification yields have been as high as 87.7 percent); some free (unreacted) glycerol glucosides; sodium soaps catalyst; inorganic salts from neutralization of sulfuric acid with soda ash; possibly some unreacted fat (glycerides); and some free fatty acids. Subsequent purification using the procedure described in "3. Material Balance," pp. 16, 18, yields a product consisting essentially of glycerol glucoside esters, possibly some unreacted fat, and some free fatty acids (about 8 percent).

The glycerol glucoside ester products consist of a mixture of compounds. The reaction between glycerol and cornstarch produces a number of different glycerol glucosides, and the proportions present in a given product depend upon the ratio of glycerol to starch used. The reaction of the glycerol glucosides with the fat produces a variety of esters of each type of glucoside. The proportions of the different glycerol glucoside esters depend upon the fatty acid composition of the fat and the ratio of fat to glycerol glucosides employed during interesterification. It follows that the composition of the glycerol glucoside esters can be tailored to a marked degree.

Generally, in the preparation of glycerol glucoside ester products an approximately 2:1 weight ratio of glycerol to starch and a 1:1 weight ratio of glycerol glucosides to fat are employed. This yields products rich in the mono- and diesters of glycerol monoglucosides.

(b) Properties. Crude and refined glycerol glucoside ester products made under the same conditions as those of the cost analysis are not quite as hard as beeswax and have a viscosity at room temperature about equal to SAE 90 lubricating oil at room temperature. At 190°C., the temperature of the process during interesterification, the crude esters are a thick liquid, pour, and can be splashed, having a viscosity about equal to SAE 40 lubricating oil when the lubricating oil is at room temperature. These esters have a specific gravity of 1.12 although gravities less than 1 have occurred.

The glycerol glucoside ester products range from very viscous oils to brittle, friable solids. Products made with cottonseed oil are viscous liquids, while those made with completely hydrogenated oils are solids that melt at about 140°F. (60°C). Individual glycerol glucoside esters isolated from the products can exist as liquid crystals over extended temperature ranges.

The lower melting products, after purification, are soluble in glyceride oils and hydrocarbons at room temperature. The higher melting products dissolve in these solvents on warming. All of the products are quite insoluble in water.

The glycerol glucoside ester products rich in mono- and diesters are very surface active. When free of soaps, the products form water-in-oil emulsions; but in the presence of moderate amounts of soaps, oil-in-water emulsions are formed. A glycerol glucoside ester product can easily be over 150 times more effective than is mono-palmitin in reducing the interfacial tension between a vegetable oil and water to one half its original value. These products are apparently even more effective in this respect than are the ordinary soaps.

(c) Uses and Markets. The glycerol glucoside ester products have many important uses as emulsifiers. So far no attempt has been made to obtain permission to use the compounds in foods. However, it is anticipated that the products can be shown to be good foods. The glycerol glucoside esters in these products are closely related to the important glycolipids of wheat flour and to the glycolipids occurring in all photosynthesizing plants.

The glycerol glucoside esters would compete with many emulsifiers now being marketed. Among the latter are the sodium and calcium stearoyl-2-lactylates, phosphatides, anhydrosorbitol esters, ethoxylated anhydrosorbitol esters, polyglycerol esters, acetylated tartaric acid esters of monoglycerides, sucrose esters, and monoglycerides.

A market study has not been made in conjunction with this cost analysis, but it has been reported in the literature that the domestic food emulsifiers market is of the order of 200 million pounds annually (12,13). In 1973, the annual production of glycerol monostearate, which is just one of the emulsifiers used in foods was over 21 million pounds (14). Production in 1973 of all glycerol esters amounted to 110 million pounds, anhydrosorbitol esters, 29 million pounds; ethoxylated anhydrosorbitol esters, 30.4 million pounds; and polyglycerol esters, 6.3 million pounds (14). Total production of surface active agents for both food and nonfood uses was 4.4 billion pounds in 1973 (14). The glycerol glucoside esters could well be the food emulsifiers of the future.

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2. DESCRIPTION OF MANUFACTURING PROCESS

Glycerol glucoside esters are prepared by a two-step process. The first step consists of reacting glycerol with cornstarch in the presence of a small, catalytic amount of acid. In the second step the acid is neutralized, an oil or fat is added, soap in the amount of about 5 percent of the total reactants is added, and the mixture is heated under vacuum to remove unreacted glycerol.

Figure 1 is a flowsheet of the batch process for producing glycerol glucoside esters. There are seven intervals in the crude esters production cycle which lasts 4 hours 40 minutes. The intervals are:

$C_3H_8O_3$ and H_2SO_4 addition and mixing (40 min.). Anhydrous glycerol is added to the reactor, N_2 gas is introduced, and the glycerol is heated to 100°C. (212°F). Concentrated sulfuric acid catalyst (0.33 percent of the sum of the weights of starch and glycerol) is added slowly, and the acid and glycerol are thoroughly mixed. The temperature of the mixture is then raised to 125°C. (257°F).

Starch addition and mixing (20 min.). One anhydroglucose unit of dry cornstarch (1 percent moisture) per 3 moles of anhydrous glycerol is added with vigorous mixing, while the reaction mixture is maintained at 125°C. Failure to maintain 125°C. causes the reaction to slow down. N_2 atmosphere is maintained.

Transglycosylation with mixing (40 min.). The reaction of starch and glycerol continues at 125°C. producing glycerol glucosides (80 percent mono- and 20 percent diglucosides). Unreacted glycerol amounting to about 70 percent of that introduced is present in the mixture.

Neutralization with mixing (5 min.). Soda ash is added slowly to neutralize the sulfuric acid while the glycerol glucosides are held at 125°C. Slow addition of soda ash minimizes foaming. pH of the mixture should be 7, or somewhere between 7 and 8, to avoid hydrolyzing the soap to be added during the next interval. N_2 atmosphere is maintained.

Addition of Na soaps and partially hydrogenated cottonseed oil (I.V. 70) with mixing (5 min.). Sodium soaps of refined edible oleic-linoleic oil, and partially hydrogenated cottonseed oil (I.V. 70) are added simultaneously causing the temperature of the mixture to drop to 91.4°C. (196.5°F.). The soaps, which are the catalyst of the interesterification, amount to 5 percent of the sum of the weights of glucosides, glycerol, sulfuric acid, and partially hydrogenated cottonseed oil. The partially hydrogenated cottonseed oil contains 0.75 equivalent of fatty acids (including associated glycerol) on the theoretical basis that all of the glycerol glucosides present are monoglucosides.

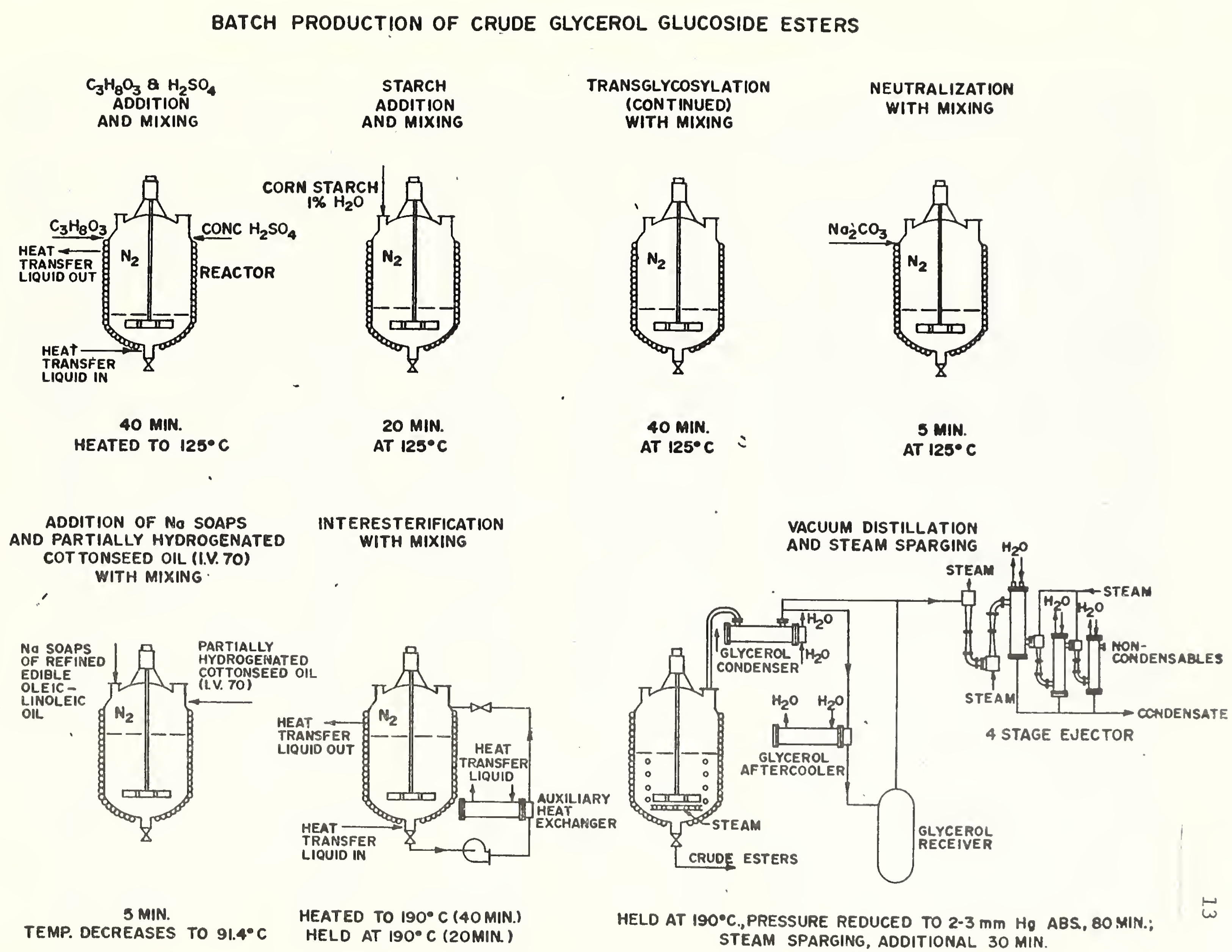

BATCH PRODUCTION OF CRUDE GLYCEROL GLUCOSIDE ESTERS
$C_3H_8O_3$ & H_2SO_4 ADDITION AND MIXING
$C_3H_8O_3$
CONC H_2SO_4
HEAT TRANSFER LIQUID OUT
N_2
REACTOR
HEAT TRANSFER LIQUID IN
40 MIN. HEATED TO 125° C
STARCH ADDITION AND MIXING
CORN STARCH 1% H_2O
N_2
20 MIN. AT 125° C
TRANSGLYCOSYLATION (CONTINUED) WITH MIXING
N_2
40 MIN. AT 125° C
NEUTRALIZATION WITH MIXING
Na_2CO_3
N_2
5 MIN. AT 125° C
ADDITION OF Na SOAPS AND PARTIALLY HYDROGENATED COTTONSEED OIL (I.V. 70) WITH MIXING
Na SOAPS OF REFINED EDIBLE OLEIC-LINOLEIC OIL
PARTIALLY HYDROGENATED COTTONSEED OIL (I.V. 70)
N_2
5 MIN. TEMP. DECREASES TO 91.4° C
INTERESTERIFICATION WITH MIXING
HEAT TRANSFER LIQUID OUT
N_2
HEAT TRANSFER LIQUID
AUXILIARY HEAT EXCHANGER
HEAT TRANSFER LIQUID IN
HEATED TO 190° C (40 MIN.) HELD AT 190° C (20 MIN.)
VACUUM DISTILLATION AND STEAM SPARGING
H_2O
STEAM
GLYCEROL CONDENSER
GLYCEROL AFTERCOOLER
STEAM
CRUDE ESTERS
GLYCEROL RECEIVER
NON-CONDENSABLES
CONDENSATE
4 STAGE EJECTOR
HELD AT 190°C., PRESSURE REDUCED TO 2-3 mm Hg ABS., 80 MIN.; STEAM SPARGING, ADDITIONAL 30 MIN.

Figure 1

Interesterification with mixing (60 min.). The reaction mixture is heated to 190°C. (374°F.) during the first 40 minutes of this interval and is held at that temperature. Interesterification begins during this time. Excess glycerol remaining unreacted from the reaction of glycerol and starch, is borrowed by the fatty acids of the cottonseed oil to form partial glycerides in situ. (Glycerol having a molecular weight of 92.1 is much more reactive than the glycerol glucosides which have a much higher molecular weight.) The partial glycerides formed are hydrophilic esters and are a mixture of mono- di-, and triglycerides, mostly monoglycerides. Glycerol associated with the fatty acids of the cottonseed oil is a coproduct of the reaction forming the partial glycerides. Interesterification of the partial glycerides and glycerol glucosides follows, releasing the same amount of glycerol as that borrowed to form partial glycerides. During this latter interesterification, the acyl radical is transferred from the mixture of mono-, di-, and triglycerides to the glycerol glucosides. N_2 is discontinued at the end of this interval.

Vacuum distillation and steam sparging (110 min.). Interesterification continues while free glycerol is removed by vacuum distillation during the first 80 minutes. The temperature is held at 190°C. while the pressure is gradually reduced to 2-3 mm. Hg absolute. During the next 30 minutes, while maintaining vacuum in the reactor, the last traces of glycerol are removed from the esters by sparging with steam having a pressure of 250 p.s.i.g.

Figure 2 is a flowsheet of the cornstarch receiving, storage, and drying systems. The cornstarch is dried to a moisture content of 1 percent or less. This moisture level in the starch expedites the reaction of cornstarch and glycerol, minimizes formation of gels, and promotes a more complete reaction.

Cornstarch is pneumatically conveyed from a rail car or a truck into the 5,000 cu. ft. storage silo at a rate of 25,000 pounds per hour. The starch is then conveyed (by means of a bin keep full system which is automatically monitored by bin level controls in the starch dryer feed bin) at a uniform rate of up to 32,000 pounds per hour from storage into the starch dryer feed bin. The starch, having a maximum moisture of 12.5 percent, is dried to 1 percent moisture at a rate of 1.2 tons per hour in the flash dryer. The drying column is 18 in. diameter x 70 ft. long, and retention time in the column is 1.2 seconds. Inlet air temperature is 400°F. but the starch remains at the wet-bulb temperature due to rapid evaporation of water. Dry starch collects in the dry starch bin where it is held under a N_2 blanket until used, usually within 24 hours. The starch is discharged into the reactor, at a predetermined time during the esters production cycle, through a rotary airlock valve and a solids flow transmitter.

(Refer to "Schedule of Operations" on pp. 89-91 for additional information directly related to the manufacturing process.)

GLYCEROL GLUCOSIDE ESTERS:
FLOWSHEET FOR CORN STARCH RECEIVING, STORAGE, AND DRYING SYSTEMS

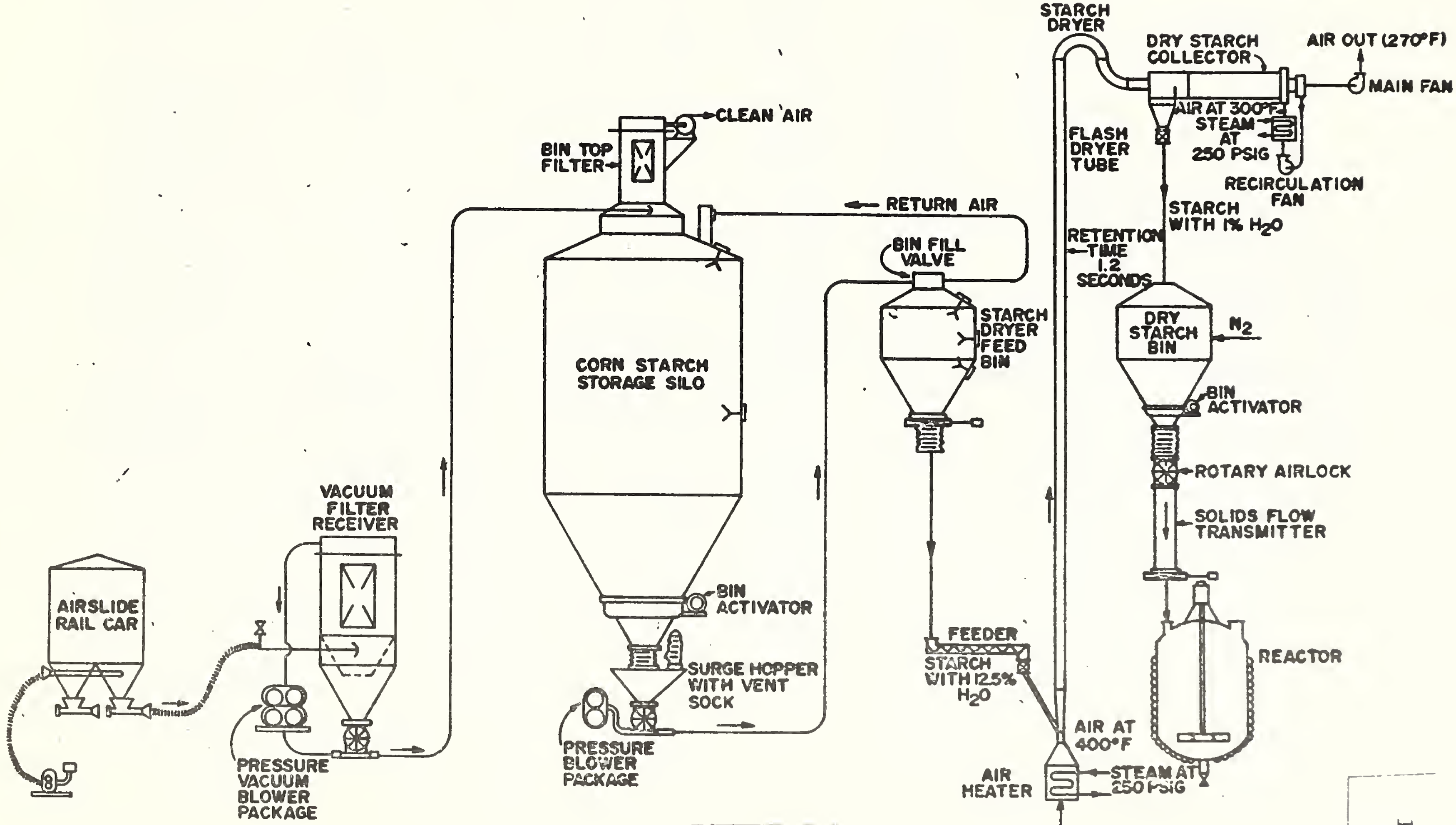


Figure 2

3. MATERIAL BALANCE

Figure 3 is a material balance for the production of a 12-ton batch of crude glycerol glucoside esters entirely from fresh raw materials. A weight ratio of 3 moles of anhydrous glycerol to 1 anhydroglucose unit of dried cornstarch is used because at lower ratios starch rings tend to attach at the wrong locations; and a ratio as low as 1 mole per 1 AGU results in nothing more than a rearrangement of starch. This material balance shows that almost 70 percent of the raw materials is converted to crude esters. Essentially all of the remainder is glycerol recovered from the esters by distillation and which can be introduced into a subsequent batch. No troublesome polluting by-products are produced.

Yield of crude esters produced entirely from fresh raw materials is 23,946 pounds per batch (or approximately 12 tons). This amount of crude esters would yield 10 tons of purified esters on the basis of yields in the laboratory using the following procedure:

(1) An amount of hexane equal to three times the weight of crude esters and an amount of water equal to 1/2 to 7/8 the weight of crude esters are added simultaneously to the warm crude esters (at 60°C. or 140°F.) so that a thick emulsion forms while mixing.

(2) An amount of water equal to 1/8 to 1/2 the weight of crude esters (whichever amount of water that in combination with the water added in (1) equals the weight of crude esters), and containing 0.67 mole of phosphoric acid per mole of sodium soaps, is then added to the crude esters-hexane-water mixture. Neutralization of the soaps in the product occurs instantaneously. Settling occurs in 1-2 minutes.

(3) The hexane layer (extract), containing purified glycerol glucoside esters amounting to 83.52 weight percent of the crude esters, is separated from the water layer containing the remainder of the esters, sodium phosphates, sodium sulfate, and free glycerol glucosides.

(4) The water layer is washed three times with hexane, using an amount of hexane in each wash equal to one half the weight of crude esters. An additional amount of purified glycerol glucoside esters, equal to 4.18 weight percent of the crude esters, is removed from the water layer by these three hexane washes. The washes, enriched with esters, are collected and can be used for hexane extraction of crude esters during purification of a subsequent batch. (Introduction of the composite of the three hexane washes, containing an additional 4.18 weight percent esters, into a subsequent batch purification increases the yield of purified esters from the subsequent batch to 87.7 percent of the crude esters.) There is no need to remove from

CRUDE GLYCEROL GLUCOSIDE ESTERS OF FATTY ACIDS

MATERIAL BALANCE

(12-TON BATCH)

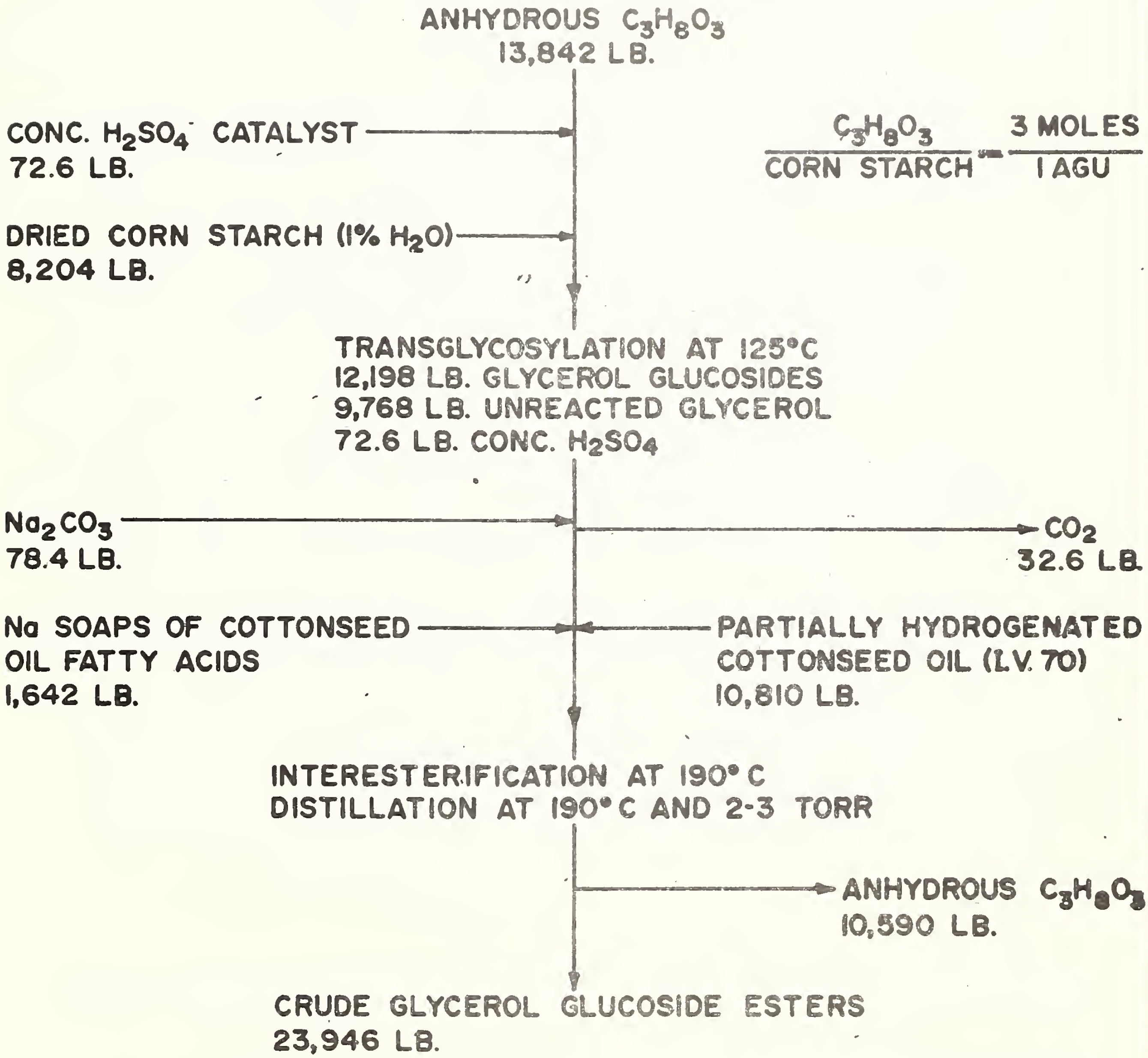


Figure 3

the hexane washes the small amount of glucosides that is washed along with esters from the water layer. Any glucosides present in the hexane washes that would find their way into the purified esters of a subsequent batch, as a result of using the hexane washes for extraction during purification of the subsequent batch, would be desirable nutritionally.

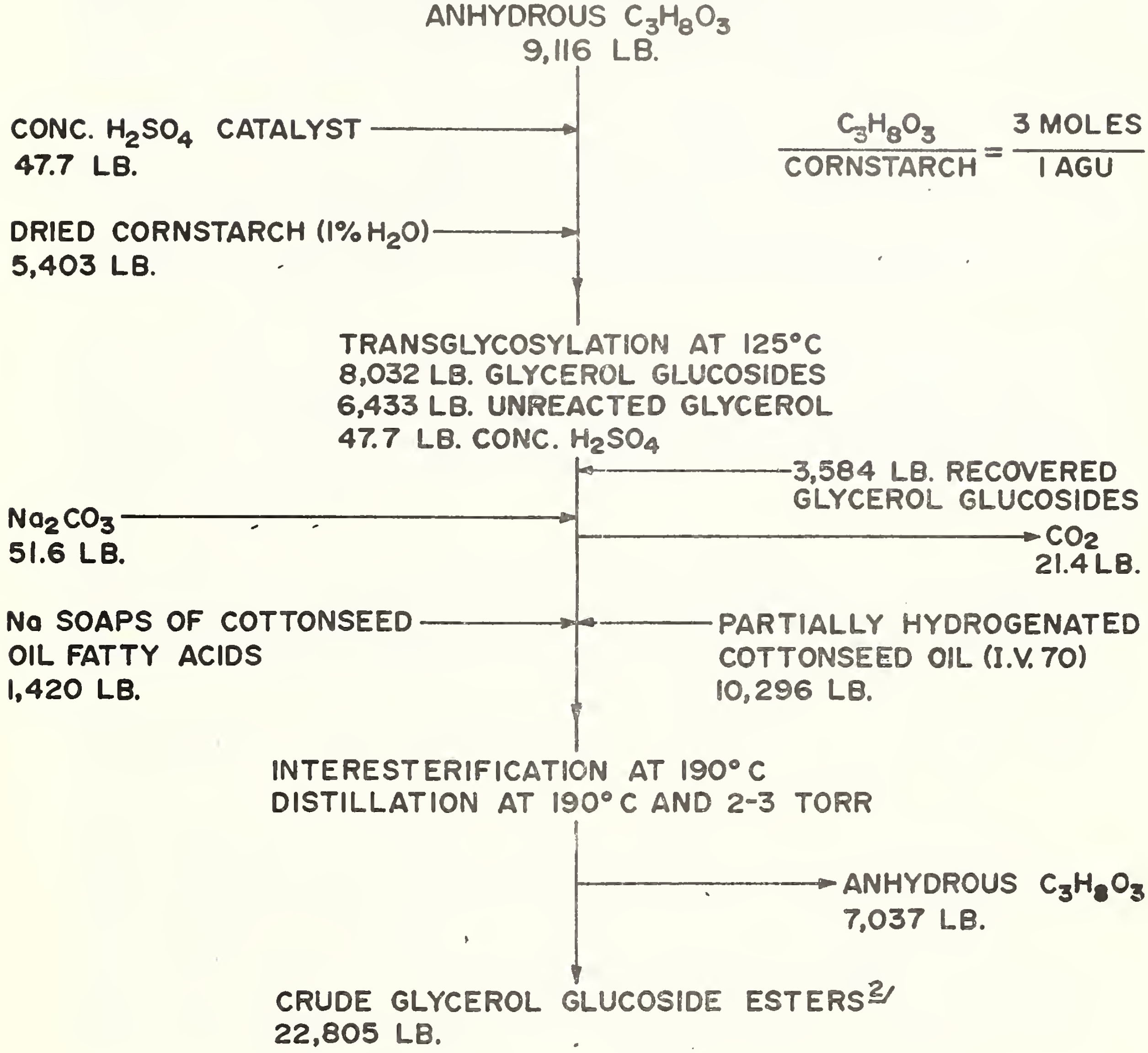
(5) Hexane is removed and recovered from the purified esters by evaporation and steam stripping under vacuum.

(6) The unreacted glycerol glucosides are recovered from the water fraction by evaporation of the water, and they can be introduced into a subsequent batch at the conclusion of transglycosylation of fresh raw materials, immediately prior to interesterification, thereby reducing consumption of fresh raw materials in the subsequent batch.

On the basis that the laboratory purification procedure described would be followed on a commercial scale and the unreacted glycerol glucosides recovered from the water fraction would be introduced into a subsequent batch at the conclusion of reaction of the fresh glycerol and starch of the subsequent batch, then the material balance of Figure 4 would apply. Substantial reduction (as much as one third reduction) in fresh cornstarch and glycerol would be effected, 13.5 percent reduction in Na soaps, and almost 5 percent reduction in partially hydrogenated cottonseed oil. Yield of crude esters would be 22,805 pounds. On the basis that the ester-enriched hexane washes of the previous batch would be used as extraction hexane in the subsequent batch, then the 22,805 pounds of crude esters would yield 10 tons of purified esters (87.7 percent yield), the same weight of purified esters as when reacting larger amounts of fresh raw materials only. This higher percentage yield would be possible because the 4.18 percent or 953 pounds of esters from the previous batch, introduced in the extraction hexane into the purification of the subsequent batch, would be recovered from the hexane in addition to that portion of the crude esters (83.52 percent) extracted by the hexane from the subsequent batch itself. Similarly, the three hexane washes of the subsequent batch would be introduced later into the purification of still another batch.

CRUDE GLYCEROL GLUCOSIDE ESTERS OF FATTY ACIDS MATERIAL BALANCE

(SUBSEQUENT BATCH)[1]



[1] Recovered glycerol glucosides, and hexane washes enriched with glycerol glucoside esters, available from purification of a previous batch, are used, reducing fresh starch and $C_3H_8O_3$ consumption by one third.

[2] An additional 953 lb. of esters are introduced subsequently during purification when the 3 hexane washes of a previous batch are used as extraction hexane, increasing total esters to 23,758 lb.

Figure 4

4. PLANT LAYOUT

Figures 5 and 6 are a layout of the process building of the 12-ton batch hypothetical plant. The process equipment shown is described fully in "5. A Complete Equipment List with Specifications and Costs for Producing Crude Glycerol Glucoside Esters" on pp. 23-49. Maximum use is made of gravity flow to conserve energy.

Glycerol and partially hydrogenated cottonseed oil storage tanks having capacities for a month's supply of those raw materials, a crude esters storage tank capable of holding two week's supply of product, and service facilities are not shown. That equipment is located outdoors with the exception of the steam boiler which is located in a separate boiler house, and the nitrogen generating system which is also housed separately.

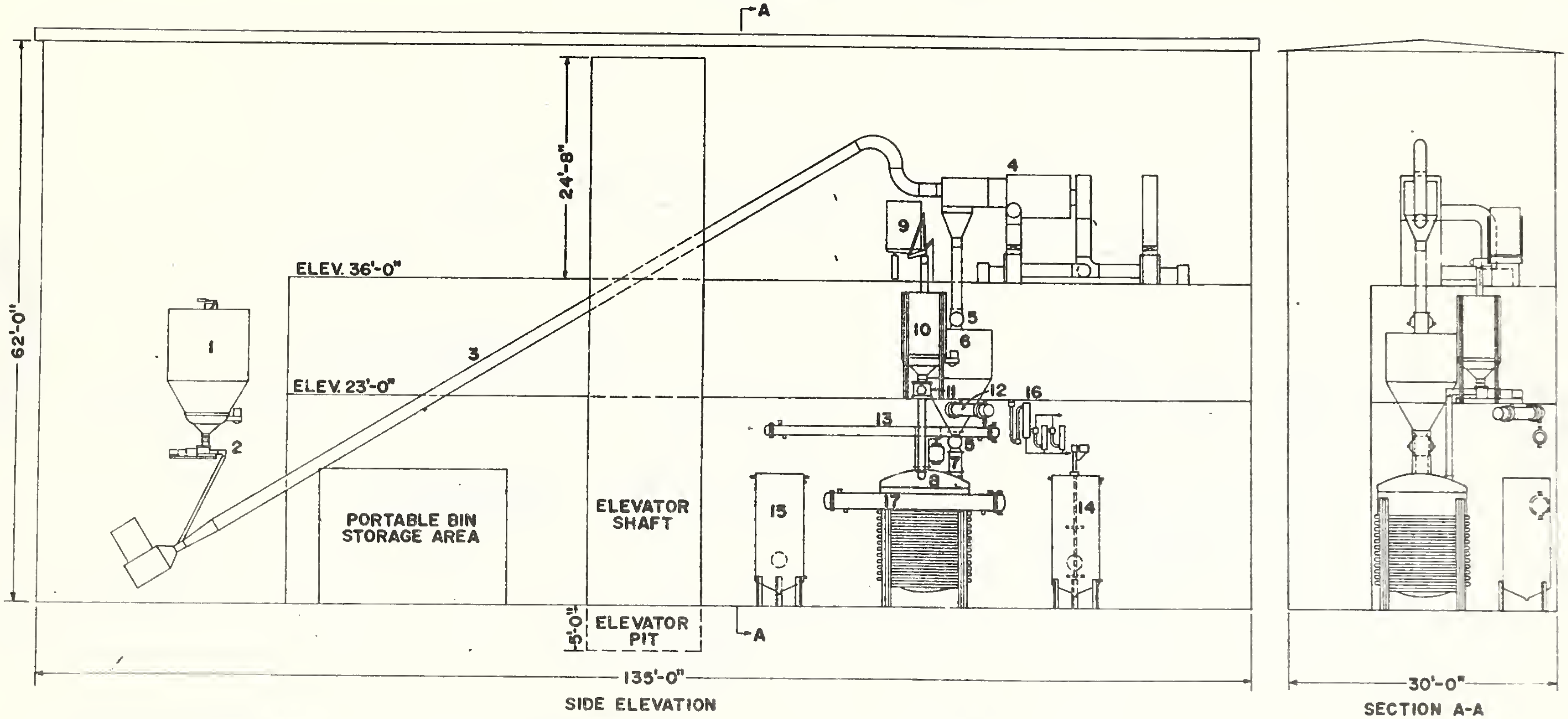
Starch flows from the dryer feed bin (Item 1 in Figure 5) through the feeder (2), through the dryer (3); and the dry starch is separated from air and collected in the collector (4), from which it passes through the rotary airlock (5) into the dry starch bin (6). As needed, it is fed through another rotary airlock (5) and the solids flow transmitter (7) into the reactor (8).

Soaps are received in portable bins (74 cubic feet holding 1 ton of soaps) which are stored on the main floor and transported as needed by forklift truck in the elevator to the bin tilt station (9) on the 2nd balcony where they are discharged into the soaps bin (10), from which they are discharged during the esters process cycle into the reactor (8).

The glycerol recovery systems (12, 13, 14, and 16), the auxiliary heat exchanger (17), and holding tanks (14, 15) are also shown.

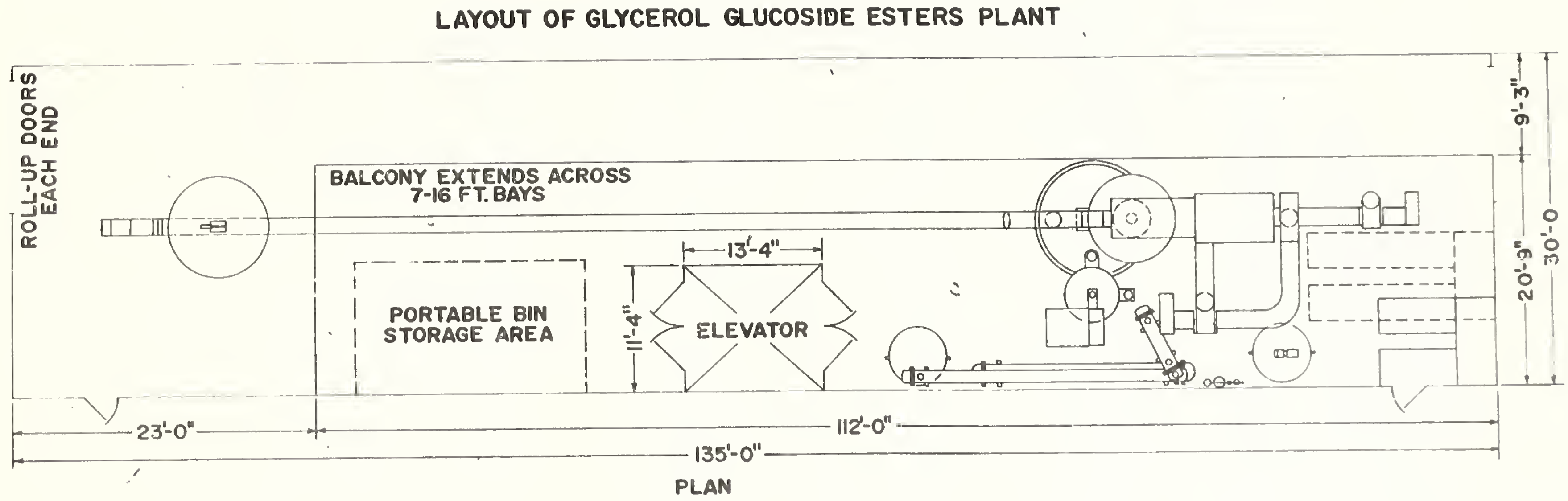
The process building measures 30 ft. wide by 135 ft. long by 62 ft. high. It is equipped with a portable overhead crane. All electrical installations are explosion-proof Class I Group D, should purification of the crude esters with hexane be undertaken. At the same time, Class I Group D is generally adequate for starch processing which is classified Class II Group G. Enough clear space is provided along one side of the inside of the building to enable moving equipment to and from the balconies using the portable overhead crane. Complete building specifications are given under "Building Costs" on pp. 75-77.

LAYOUT OF GLYCEROL GLUCOSIDE ESTERS PLANT



1. STARCH DRYER FEED BIN
2. STARCH DRYER FEEDER
3. STARCH DRYER
4. DRY STARCH COLLECTOR
5. ROTARY AIRLOCK
6. DRY STARCH BIN
7. SOLIDS FLOW TRANSMITTER
8. REACTOR
9. SOAPS GRAVITY TILT STATION
10. SOAPS HOLDING BIN
11. SOAPS FEEDER
12. GLYCEROL CONDENSER
13. GLYCEROL AFTERCOOLER
14. GLYCEROL HOLDING TANK
15. PARTIALLY HYDROGENATED COTTONSEED OIL HOLDING TANK
16. 4-STAGE STEAM JET EJECTOR
17. AUXILIARY HEAT EXCHANGER

Figure 5



LAYOUT OF GLYCEROL GLUCOSIDE ESTERS PLANT
ROLL-UP DOORS EACH END
BALCONY EXTENDS ACROSS 7-16 FT. BAYS
PORTABLE BIN STORAGE AREA
ELEVATOR
13'-4"
11'-4"
9'-3"
20'-9"
30'-0
23'-0"
112'-0"
135'-0"
PLAN

Figure 6

5. A COMPLETE EQUIPMENT LIST WITH SPECIFICATIONS AND COSTS FOR PRODUCING CRUDE GLYCEROL GLUCOSIDE ESTERS

The following equipment list includes specifications and costs of equipment for a hypothetical commercial plant having a capacity of one 12-ton batch of crude glycerol glucoside esters per 8-hour shift of operations.

The equipment described has been recommended by equipment manufacturers in fulfillment of engineering specifications prepared at the Southern Regional Research Center (SRRC) in the course of the plant design and cost study. The specifications were based on and developed from laboratory research data.

The list includes:

I. Cornstarch Receiving, Storage, Drying, and Transfer Equipment (Figure 2 on p. 15.)

II. Sodium Soaps Receiving, Storage, and Transfer Equipment

III. Crude Esters Process Equipment (including Glycerol Recovery) (Figure 1 on p. 13.)

IV. Raw Materials and Product Storage Equipment

V. Service Facilities

- A. Heat Transfer Liquid System
- B. Nitrogen Generating System
- C. Steam Boiler and Accessories
- D. Cooling Tower and Accessories
- E. Offsite Electric Distribution System

A summary of the equipment appears in Table II on pp. 69-72.

I. CORNSTARCH RECEIVING, STORAGE, DRYING, AND TRANSFER EQUIPMENT (Refer to Figure 2 on p. 15.)

A. 4-INCH DIA. RAIL CAR/TRUCK UNLOAD & STORAGE SYSTEM

Vacuum-Pressure Pneumatic Conveying System, designed to transport powdered edible corn starch at a uniform rate, conveying 25,000 pounds per hour from rail car or truck to a vacuum filter receiver, a maximum distance of 20 ft. horizontal, 10 ft. vertical, including a maximum of two 90° elbows or their equivalent; and from the filter receiver to the storage silo, a maximum distance of 10 ft. horizontal, 65 ft. vertical, with 2 elbows. All surfaces coming in contact with the starch are to be fabricated of aluminum, 304 SS, or epoxy coated carbon steel unless noted.

The components of this system are as follows:

Combination Vacuum-Pressure Blower Package, complete with drive, drive guard, vacuum and pressure gage relief valves, expansion joint, check valve, air intake filter, discharge silencer and mounting base. Driven by 50 HP, 1800 r.p.m., 3/60/230/460 explosion proof motor.

Price f.o.b. factory $ 8,500

Rotary Airlock Feeder, of cast iron construction, 1.2 cu. ft. displacement, bronze rotor tips, complete with roller chain drive, guard, mounting base, and driven by 1 HP, 25 r.p.m., 3/60/230/460 explosion proof right angle gearmotor. Equal to Fluidizer, Inc. AFC-12 Feeder.

Price f.o.b. factory $ 3,800

Vacuum Filter Receiver (Filter-Separator), of carbon steel construction. Complete with 108 sq. ft. filter bags, which are cleaned by a reverse flow of air (6 c.f.m. of 100 p.s.i.g. air). Includes solenoid timer, relief valve, access door, support legs, and discharge adaptor for Rotary Airlock. Unit to have tangential entry and epoxy coated interior. Equal to Fluidizer, Inc. FR962-A Filter-Separator.

Price f.o.b. factory $ 5,200

Conveying Line, 4 in. O.D. by 1/8 in. wall aluminum tubing, consisting of the following components:

- 5 20 ft. sections of straight
- 4 90^{o} long sweep elbows
- 10 compression couplings
- 2 15 ft. flexible rubber hose assembly complete with adapters
- 1 vacuum breaker and tee connection
- 1 truck control box

Price f.o.b. factory $ 3,100

Bin Top Filter (Filter-Separator), of carbon steel construction. Complete with 108 sq. ft. filter bags. Includes solenoid timer, access door, tangential entry adapter, epoxy coated interior, housing bottom grill and exhauster with 3 HP explosion proof motor. Equal to Fluidizer, Inc. BV961-A Filter-Separator.

Price f.o.b. factory $ 4,300

Pick-Up Adapter and Air Filter, for rail car equipped with pneumatic nozzle. Adapter to be all aluminum construction. 2 each.

Price f.o.b. factory $ 1,200

Rail Car Blower Package, complete with drive, drive guard, air inlet filter, pressure gage, pressure relief valve, expansion joint, check valve and mounting base. Driven by 7 1/2 HP, 1800 r.p.m., 3/60/230/460 explosion proof motor. Equal to Fluidizer, Inc. FPB 63 blower package.

Price f.o.b. factory $ 2,750

Storage Silo, with support skirt, providing 5000 cu. ft. of storage. Approximately 12 ft. dia. x 65 ft. high, of mild steel construction. Epoxy coated interior, primer with enamel finish on exterior. Storage bin will be complete with: access hatch (pressure/vacuum relief type); 3 bin level switches and mounting brackets, 60 degree hopper and adapter for an including 4 ft. dia. live bottom equal to Vibra Screw Inc. bin activator described in Bulletin BA-71 driven by an explosion proof motor; filter or breather mounting flange; support skirt vent and access door; access ladder with safety cage; guard rail and toe plate on bin roof; and necessary catwalk and ladders for access to air filter. Excludes footings, foundations, and installation. Equal to Fluidizer, Inc. Storage Bin FSB-1250A.

Price f.o.b. factory $28,000

Total Price of "A", f.o.b. factory
excluding freight and taxes $56,850

B. 4-INCH DIA. TRANSFER SYSTEM

Pressure Pneumatic Conveying System, designed to transport powdered edible corn starch at a uniform rate, conveying 32,000 pounds per hour from storage silo to starch dryer feed bin, a maximum distance of 30 ft. horizontal, 30 ft. vertical, including a maximum of two 90° elbows or their equivalent. A bin keep full system is automatically monitored by the bin level controls in the starch dryer feed bin. All surfaces coming in contact with the starch are to be fabricated of aluminum or epoxy coated carbon steel unless noted.

The components of this system are as follows:

Pressure Blower Package, complete with drive, drive guard, pressure gage relief valve, expansion joint, check valve, air intake filter, discharge silencer and mounting base. Driven by 30 HP, 1800 r.p.m., 3/60/230/460 explosion proof motor. Equal to Fluidizer, Inc. Blower Package FPB1041.

Price f.o.b. factory $ 5,980

Rotary Airlock Feeder, of cast iron construction, 1.2 cu. ft. displacement, bronze rotor tips, complete with roller chain drive, guard, mounting base, and driven by 1 HP, 25 r.p.m., 3/60/230/460 explosion proof right angle gearmotor. Equal to Fluidizer, Inc. AFC-12 Feeder.

Price f.o.b. factory $ 3,800

Surge Hopper, all welded carbon steel construction with air relief to vent sock.

Price f.o.b. factory $ 675

Starch Dryer Feed Bin, approximately 6 ft. dia. by 11 ft. high, 300 cu. ft. capacity of welded aluminum construction, complete with pneumatic inlet, access door, hanger brackets, and 8 in. dia. automatic discharge gate. Unit includes 6 bin flow pads, 3 level controls, and flex shroud.

Price f.o.b. factory $ 5,600

Conveying Line, 4 in. O.D. by 1/8 in. wall aluminum tubing, consisting of the following components:

- 5 20 ft. sections of straight tubing
- 4 90^{o} long sweep elbows
- 10 compression couplings
- 1 bin fill valve of aluminum construction, 304 SS flipper, air piston operated with one 4-way 110/220V solenoid valve for 80 to 125 p.s.i.g. plant air, and 2 pre-wired explosion proof micro-switches. Equal to Fluidizer, Inc. BF40-B bin fill valve.

Price f.o.b. factory $ 2,600

Electrical Controls. Control panel to be located in its own shelter anywhere between the railroad siding and the process building, will be of NEMA 12 construction with graphic face, enamel finish, industrial type relays, oil tight buttons, selector switches and indicating lights. H-0-A switches for motors and automatic valves. Includes 1 panel, pressure or vacuum switch, 6 bin level switches, 3 auxiliary stations. Breakers, starters, or main disconnect excluded.

Price f.o.b. factory $ 6,000

Total price of "B", f.o.b. factory excluding freight and taxes $24,655

C. STARCH DRYER SYSTEM

Tube type dispersion dryer for drying 1.2 tons of starch per hour from a maximum initial moisture of 12.5% to a final moisture of 1%. Steam consumption is 1400 pounds of 250 p.s.i.g. steam per hour. All starch contact surfaces are to be of 304 SS, and motors are to be Class I Group D. System includes:

Primary air fin tube heat exchangers and controls, for heating process air to $400^{o}F$.

Volumetric starch feeder and drive, 1 HP motor, automatically controlled by means of a present outlet air temperature controller. Equal to 4" Vibra Screw Heavy Duty Feeder Model HD-2 with 304 SS contact parts.

Rotary airlock, between feeder and dispersing venturi, 1/2 HP motor.

Dryer feed dispersing venturi.

Drying column, approximately 18 inches in diameter by 80 feet long, 1.2 seconds retention time.

Starch conveying ducts.

Starch collector and rotary discharge valve. Collector equal to Aerodyne Development Corporation Series "SV" Dust Collector. Discharge valve is rotary airlock type with 1/2 HP motor.

Secondary air fin tube heat exchangers and controls, for preheating secondary air to the collector to 300°F, to provide secondary or final moisture removal from the dry starch prior to separation.

Exhaust ducts.

Main exhaust fan, damper, drive and motor, 25 HP, discharges air at 270°F.

Secondary air blower, damper, drive and motor, 15 HP.

Equal to flash dryer by Komline-Sanderson Engineering Corporation, Peapack, N. J., their Study Sketch No. 1, entitled "General Assembly, 18" x 80'-0" Flash Dryer, USDA-SRRC, New Orleans, La."., dated November 12, 1975.

Approx. price f.o.b. factory	$57,000

Explosion suppression system for the above dryer, depending upon the number of outlets required.

Price installed	$10,000-$14,000
Total price of "C" excluding freight and taxes[b/]	$67,000-$71,000

(Note: Dryers of other types are not excluded, as long as they have an efficiency and capability equal to that of flash drying, and as long as starch is not brought in contact with flue gases, and a safe operation can be established and maintained.)

D. DRY STARCH SYSTEM

This system is for receiving dry cornstarch (containing 1% moisture) from the starch dryer, and for discharging the dry starch from the dry starch bin into the reactor. Starch discharge rate into the reactor is 410.2 pounds per minute for 20 minutes, occurring once for each 12-ton batch of crude esters, during the starch addition and mixing step of the process cycle. All starch contact surfaces are to be fabricated of aluminum, 304 SS, or epoxy coated carbon steel unless noted.

b/ Actually includes freight and taxes of explosion suppression system for which only an installed price was available.

The components of this system are as follows:

Dry Starch Bin, approximately 8 ft. dia. by 12 ft. high, 350 cu. ft. capacity, of welded aluminum construction, complete with 3 level controls, gravity feed inlet, access door, hanger brackets and 48-in. dia. discharge opening. Attached to opening is to be a 4-ft. dia. live bottom with epoxy coating equal to Vibra Screw Inc. bin activator described in Bulletin BA-71 driven by a 1 1/2 HP explosion proof motor. Also includes flex shroud with emergency cutoff gate.

Rotary Airlock Feeder, of cast iron construction, 1.2 cu. ft. displacement, bronze rotor tips, complete with motor and drive to be used in conjunction with signal generated by solids flow transmitter. Equal to Fluidizer, Inc. RA-12 Feeder.

Solids Flow Transmitter, fabricated of 304 SS at all points of contact with starch, equal to Size 5 Yarway Corporation solids flow transmitter. Complete with electromechanical predetermining counter. Set to operate on a controlled feed basis. Controller to modulate the speed of the variable speed drive of the rotary airlock feeder, to produce rate of starch feed selected by the operator.

Total price of "D", f.o.b. factory excluding freight and taxes	$24,000
Total price, I. Corn Starch Receiving, Storage, Drying and Transfer Equipment, f.o.b. factory excluding freight and taxes	$172,505-$176,505

II. SODIUM SOAPS RECEIVING, STORAGE, AND TRANSFER EQUIPMENT

Powdered sodium soaps of refined edible oleic-linoleic oil are to be received from the manufacturer in 74 cu. ft. portable bins, each containing one ton of soaps. The bins will be unloaded from the carrier using a fork lift truck, and stacked two high on the main floor of the process building. (Refer to "Portable Bin Storage Area" in Figure 5 on p. 21.) The bins are to be transported, as needed, by a fork lift truck via the freight elevator to the bin gravity tilt station on the second balcony, and the soaps discharged into the soaps holding bin. They are discharged later from the holding bin into the reactor at a rate of 656 pounds per minute (or 24.9 c.f.m.) for 2.5 minutes during the process cycle. The empty bins are returned to the main floor for shipment to the manufacturer for refilling.

The sodium soaps system includes:

Portable Bins, 74 cubic feet each, with center top opening and side door discharge, fabricated of carbon steel, sand-blasted on the inside, with 3 mil prime and finish epoxy coating on the inside. Equal to Tote Bin Type A-74. 40 required. (13 bins supply enough soaps for 3-4 weeks operation. 40 allows for 13 bins at the manufacturer's plant, 13 at the esters plant, and 13 in transit, with 1 spare.)

Price f.o.b. factory (40 at $609.50 each) =	$24,380

Gravity Tilt Station, with screw conveyor. Equal to the Tote Tilt A-74.

Price f.o.b. factory	$ 3,300

Soaps Holding Bin, 60 in. dia. by 48 in. on the straight side, overall height of 136 1/8 in., capacity of 150 cu. ft. Equipped with live bottom to assure positive discharge of powdered sodium soaps. Equal to Vibra Screw Incorporated's Live Bottom Bin LBB5-150 with cone baffle, bin cover, epoxy coating on bin and cover, equipped with a 1 1/2 HP explosion proof motor. Complete with 4 legs.

Price f.o.b. factory	$ 8,579

Soaps Feeder, volumetric, for feeding soaps at a rate of 24.9 c.f.m. into the reactor. Equal to Vibra Screw Incorporated's 8 in. heavy duty feeder, Model HD-2, with 304 SS in contact with soaps. Complete with a 1 1/2 HP explosion proof motor.

Price f.o.b. factory	$ 5,251
Total price, "II. Sodium Soaps Receiving, Storage, and Transfer Equipment," f.o.b. factory excluding freight and taxes	$41,510

III. CRUDE ESTERS PROCESS EQUIPMENT (INCLUDING GLYCEROL RECOVERY)

Production of 12-ton batches of crude glycerol glucoside esters occurs in this equipment. The production cycle last 4 hours and 40 minutes as illustrated in Figure 1 on p. 13. The equipment grouping includes:

Reactor, 114 in. diameter vessel having a gross volume of 5,550 gallons, with all parts contacting the product constructed of type 316 SS. Designed for full vacuum internal operation and 100 p.s.i.g. jacket pressure, all in accordance with the latest A.S.M.E. Code, complete with Inspection and Stamp.

Top Head: A.S.M.E. Flanged and Dished, welded to the shell with the following openings:

1 - 18 in. manway with hinged cover
1 - 18 in. x 150 lb. flanged starch charge nozzle
1 - 10 in. safety nozzle with rupture disc
1 - 10 in. agitator nozzle at center
5 - 4 in. x 150 lb. flanged nozzles

Bottom Head: A.S.M.E. Flanged and Dished, welded to the shell with the following opening:

1 - 4 in. pad with flush bottom outlet valve for drain

Jacket: Half-pipe type, 3 in. nominal size, 1/8 in. wall, of 304 SS, over the bottom head and approximately 96 in. of the vessel straight side, with 2 in. x 300 lb. inlet and outlet nozzles. Multiple zones as required to control pressure drop. One inch spacing between jacket coils, 410 sq. ft. jacket surface.

Support: 4 to 6 legs of such length as to place the bottom of the reactor approximately 24 in. above the floor.

Agitation: To consist of a 20 HP, 230/460 volt, 3 phase, 60 hz, Class I Group D vertical agitator drive having an output speed of 84 r.p.m. Agitator has 45 in. diameter pitched blade turbine. Four vertical baffles mounted from the shell prevent swirling.

Price f.o.b. factory $65,000

C. STEAM BOILER AND ACCESSORIES

The steam boiler supplies 13,000 pounds of 250 p.s.i.g. steam to process each 12-ton batch of crude glycerol glucoside esters as follows:

Steam Supplied To:	Time, hrs.	Rate, lbs./hr.	Total, lbs./batch
Starch dryer	4 1/3	1,400 (S)	6,062
Reactor for esters sparging following glycerol distillation	1/2	2,400 (S)	1,200
Tank car and glycerol storage tank, to heat contents in cold weather (prorated among all batches on the basis of being required 1/4 of the time)	1	5,097 1/ (NNS)	682
Steam ejector, for 2-3 mm. Hg vacuum on reactor during glycerol distillation	2	325 (S)	650
Crude esters storage tank, to heat product before pumping to tank car for shipment (prorated among all batches on the basis of heating full tanks containing 10 batches in 4 hours)	4	1,296 1/ (NNS)	518
Totals		4,125 (S) +6,393 (NNS)	9,112

$$9{,}112/0.70^{2/} = 13{,}000 \text{ lbs./batch}$$

S = Simultaneous supply

NNS = Not necessarily simultaneous supply

1/ On basis that tank is full when heating occurs.

2/ 30 percent heat loss in distribution.

Auxiliary Heat Exchanger, 1265 sq. ft., for heating 2033 lbs./min. (210 g.p.m.) esters-glycerol mixture on tube side from 255.5°F to 374°F (124.2°C to 190°C) in 40 minutes during interesterification; heat transfer liquid (e.g., Therminol 55, Mobiltherm 603, Dowtherm G) on shell side, in at 450°F, out at 425°F, at a rate equivalent to 4,698 lbs./min. (762.8 g.p.m.) Mobiltherm 603; all surfaces contacting esters-glycerol mixture 304 SS. Equal to American Standard Incorporated's size 19222, C-200K heat exchanger.

Price f.o.b. factory $19,627

Glycerol Condenser, 134 sq. ft., for condensing 132.4 lbs./min. (12.6 g.p.m.) glycerol vapor on shell side at 374°F.; cooling tower water on tube side, in at 85°F., out at 120°F., at a rate of 1,388 lbs./min. (166.4 g.p.m.); all surfaces contacting glycerol 304 SS. Operating press. as low as 2-3 mm. Hg abs. on shell side. Equal to American Standard Incorporated's size 15060, C-250K heat exchanger.

Price f.o.b. factory $10,957

Glycerol Aftercooler, 565 sq. ft., for cooling condensed glycerol on tube side at a rate of 132.4 lbs./min. (12.6 g.p.m.) from 374°F. down to 120°F.; cooling tower water on shell side, in at 85°F., out at 120°F., at a rate of 652 lbs./min. (78.2 g.p.m.); all surfaces contacting glycerol 304 SS. Operating press. as low as 2-3 min. Hg abs. on tube side. Equal to American Standard Incorporated's size 12288, C-200K heat exchanger.

Price f.o.b. factory $10,065

Reactor Pump, 210 g.p.m., 316 SS, to pump reaction mixture through auxiliary heat exchanger and back into reactor during interesterification, 35 ft. dynamic head. The reaction mixture is at 374°F, has a specific gravity of 1.156, and a viscosity at 374°F about equal to viscosity of SAE 40 lubricating oil at 70°F 2150 (~~820~~ SUS). Equal to Goulds Pumps, Inc. Model 3196 MT (open impeller centrifugal process pump), bedplate, coupling, coupling guard, jacketed stuffing box cover, mechanical seal, complete with Class I Group D motor.

Price f.o.b. factory $ 2,875

<u>Steam Jet Ejector</u>, 4-stage, with surface type intercondensers and aftercondenser, for establishing and maintaining 2-3 mm. Hg abs. pressure in the reactor during the batch distillation of glyercol from the reaction mixture. So that interesterification can proceed satisfactorily during distillation, the temperature of the reaction mixture is maintained at 374°F. Reduction of pressure is gradual, from about 15 mm. Hg (partial pressure at which most glycerol distills at 374°F, as determined by Raoult's Law) down to 2-3 mm. Hg. Design should be on the basis that distillation rate averages 12.6 g.p.m. for the 80-minute period; 25.2 g.p.m. initially at 15 mm. Hg abs. pressure and diminishing linearly to a negligible rate during the last minute at 2-3 mm. Hg.

On completion of distillation, while 2.5 mm. Hg abs. pressure is maintained by the ejector, 250 p.s.i.g. sparge steam is injected into the reaction mixture for 30 minutes to remove remaining traces of glycerol.

Initial ejector stage(s) and first intercondenser to be of 304 SS.

Price f.o.b. factory $12,500

<u>Glycerol Holding Tank</u>, 2,000 gallons, 304 SS, 1/4 in. plate, 5 ft. 4 in. diameter x 12 ft. high vertical tank (along the straight side), coned bottom. Equipped with 6 in. welding neck flange to receive top entering agitator; a 1 1/2 in. diameter x 180 ft. long spiral-helical low-pressure steam coil at bottom; manhole; 2-2 1/2 in. couplings at or near the top; 4 in. coupling at the bottom; 2-1 in. couplings on side for liquid level indicator; with 4-3 in. x 3 in. x 1/4 in. steel angle legs, 34 in. long, welded to tank with at least 4 in. of 1/4 in. weld each leg, setting tank 18 in. above floor level. (Weight of liquid when tank is full is 21,000 pounds.)

Price f.o.b. factory $ 5,090

<u>Mixer for Glycerol Holding Tank</u>, for intermittent use along with heating coil to discourage freezing of glycerol during the winter months. Temperature of 99.5 percent c.p./U.S.P. glycerol in tank can range from 62.4°F (glycerol's melting point) to 120°F (the temperature at which glycerol collects in the holding tank on being discharged from the aftercooler during distillation). Over this temperature range, specific gravity varies from 1.2633 at 62.4°F to 1.2431 at 120°F. Viscosity is 180 cp. at 120°F and 1960 cp. at 62.4°F. Agitator

shaft is 2 in. dia. extending approximately 132 in. below the mounting flange. Shaft mounts two 25 in. dia. 4-blade axial turbines rotating at 86 r.p.m. Lower turbine is located 18 in. above tangent line and spacing is 50 in. Mixer mounting flange is standard 6 in. - 150 lb. ANSI with integral packed stuffing box using graphited asbestos packing. Shaft has a stabilizer ring located below the lower turbine. All wetted parts are 304 SS. Mixer is powered by a 2 HP 1800 r.p.m. 230/460/3/60 explosion proof motor. Tank to have four equally spaced sidewall baffles, each 5 in. wide mounted 1 in. off tank wall. Equal to ProQuip, Inc. Model 2ZCS20M top entering right angle gear driven turbine type mixer.

Price f.o.b. factory $ 3,000

Recovered Glycerol Pump, 55 g.p.m., 316 SS to pump recovered 99.5% c.p./USP glycerol from glycerol holding tank to reactor, 25 ft. dynamic head. Glycerol is at 100° to 120°F, has a corresponding viscosity of 350 to 180 cp., and a specific gravity of 1.2503 to 1.2431. May be necessary to use pump also at 62.4°F for recycling of glycerol during warming of glycerol in holding tank prior to pumping to reactor, in which case specific gravity would be 1.2633 and viscosity 1.960 cp., 12 ft. dynamic head. Equal to Viking Heavy Duty Alloy Pump L724R (positive displacement rotary pump), 230 r.p.m., complete with 5 HP Class I Group D motor.

Price f.o.b. factory $ 2,530

Glycerol-Water Pump, 5 g.p.m., 316 SS, to pump 90.5 mole percent glycerol/9.5 mole percent water solution (same as 98 weight percent glycerol/2 weight percent water solution) from 50-gallon glycerol-water receiver to drums, 20 ft. dynamic head. Solution is at 100° to 120°F, has a specific gravity of 1.2569, and a viscosity of 250 cp. Equal to Goulds Pumps, Inc. Model 3199 (single stage, open impeller, end suction, centrifugal pump), size 1x1-5, bedplate, coupling, coupling guard, mechanical seal, complete with 2 HP, 1800 r.p.m., Class I Group D motor.

Price f.o.b. factory $ 830

Partially Hydrogenated Cottonseed Oil Holding Tank, 2000 gallons, carbon steel, 7 gage (3/16 in.) plate, 5 ft. 4 in. diameter x 12 ft. high vertical tank (along the straight side), coned bottom. Equipped with manhole; 2-2 1/2 in. couplings at or near the top; 4 in. coupling at the bottom; 2 - 1 in. couplings on side for

liquid level indicator; with 4 - 3 in. x 3 in. x 1/4 in. steel angle legs, 34 in. long, welded to tank with at least 4 in. of 1/4 in. weld each leg, setting tank 18 in. above floor level. (Weight of liquid when tank is full is 15,200 pounds.)

Price f.o.b. factory $ 1,375

Partially Hydrogenated Cottonseed Oil Pump, 284.5 g.p.m. carbon steel and/or 316 SS, to pump partially hydrogenated cottonseed oil (I.V. 70), a plastic fat containing less than 12 percent solids, from surge tank into reactor, 20 ft. dynamic head. The plastic fat is at 85°F, has a specific gravity of 0.91 and a viscosity of 60 cp. Equal to Viking Heavy Duty Pump QR124R (positive displacement rotary pump), 520 r.p.m. complete with 15 HP Class I Group D motor.

Price f.o.b. factory $ 3,800

Crude Esters Pump, 120 g.p.m., 316 SS, to pump crude glycerol glucoside esters from reactor to storage tank or rail car, 35 ft. dynamic head. The esters are at 70°F, have a specific gravity of 1.112 and a viscosity of approximately 285 cs. Equal to Goulds Pumps, Inc. Model 3196 MT (open impeller centrifugal process pump), size 2x3-8, bedplate, coupling, coupling guard, mechanical seal, complete with 7 1/2 HP, 1800 r.p.m., Class I Group D motor.

Price f.o.b. factory $ 1,766

Total price, "III Crude Esters Process Equipment (Including Glycerol Recovery)", f.o.b. factory excluding freight and taxes $139,415

IV. RAW MATERIALS AND PRODUCT STORAGE EQUIPMENT

In addition to the cornstarch and sodium soaps storage and transfer equipment listed in I and II of this equipment list, the following equipment is provided for storage and transfer of other raw materials used and the crude esters product. Concentrated sulfuric acid and sodium carbonate (soda ash) are used in such small quantities that measured amounts are introduced into the reactor from 55-gallon drums and 100-pound bags, respectively.

Glycerol Storage Tank, 5,000 gallons, 304 SS, 1/4 in. plate, 8 ft. diameter x 13 ft. 6 in. vertical tank (along the straight side), coned bottom. Equipped with two beams spanning the flat top to support mixer weight and torque; standard low pressure vapor and dirt seal to receive top entering mixer consisting of flexible rubber-face type seal held to the mixer shaft by garter spring rotating with it, the seal face bearing against the upper surface of the top of tank; a 1 1/2 in. dia. x 210 ft. long spiral-helical low-pressure steam coil at bottom; 20 in. manhole; 2 - 2 1/2 in. couplings at or near the top; 2 in. coupling at the bottom; 2 - 1 in. couplings on the side wall for liquid level indicator; with 6 - 3 in. x 3 in. x 1/4 in. steel angle legs, 42 in. long, welded to tank with at least 4 in. of 1/4 in. weld each leg, setting tank 18 in. above floor level. (Weight of liquid when tank is full is 52,500 pounds.)

Price f.o.b. factory $11,400

Mixer for Glycerol Storage Tank, for intermittent use along with heating coil to discourage freezing of glycerol during the winter months, and to promote uniform heating prior to pumping, at the same time avoiding localized overheating near the steam coil and the off color that results. Temperature of 99.5% c.p./USP glycerol in tank can range from 62.4°F (glycerol's melting point) to 100°F which is the minimum recommended temperature for pumping glycerol. Specific gravity varies from 1.2633 at 62.4°F to 1.2503 at 100°F. Viscosity is 350 cp. at 100°F and 1.960 cp. at 62.4°F. Agitator shaft is 2 1/2 in. diam. extending approximately 144 in. below the mounting flange. Shaft mounts two 35 in. dia. 4-blade axial turbines rotating at 60 r.p.m. Lower turbine is located 24 in. above tangent line, and turbine spacing is 66 in. Mixer mounting flange is standard 6 in. 150 lb. ANSI with integral packed stuffing box using graphited asbestos packing. All wetted parts are 304 SS.

Mixer is powered by a 3 HP, 1750 r.p.m., 230/460/3/60 explosion proof motor. Tank to have four equally spaced sidewall baffles, each 6 in. wide mounted approximately 1 in. off tank wall. Equal to ProQuip, Inc. Model 3ZES30M top entering right angle gear driven turbine type mixer.

Price f.o.b. factory $ 3,234

Glycerol Storage Pump, 50 g.p.m., 316 SS, to pump 99.5 percent c.p./USP glycerol from tank car or tank truck into storage tank, 25 ft. dynamic head. Glycerol is at 100° to 120°F, has a corresponding viscosity of 350 to 180 cp. and specific gravity of 1.2503 to 1.2431. May be necessary to use pump also at 62.4°F for recycling of glycerol during warming of glycerol in tank car prior to pumping to storage tank, in which case specific gravity is 1.2633 and viscosity 1.960 cp., 20 ft. dynamic head. Equal to Viking Heavy Duty Alloy Pump L724 R (positive displacement rotary pump), 230 r.p.m., complete with 5 HP TEFC motor.

Price f.o.b. factory $ 2,400

Glycerol Pump, same as previous item except pump is to be used for transporting glycerol from storage tank to reactor.

Price f.o.b. factory $ 2,400

Partially Hydrogenated Cottonseed Oil Storage Tank, 25,000 gallons, carbon steel, 5/16 in. plate, 12 ft. diameter x 30 ft. vertical tank (along the straight side), coned bottom. Equipped with 20 in. manhole; 2 - 4 in. couplings at or near the top; 4 in. coupling at the bottom; 5 - 1 in. couplings on the side wall for liquid level indicators; with 6 - 6 in. x 6 in. x 3/8 in. steel angle legs, 58 in. long, welded to tank with at least 10 in. of 3/8 in. weld each leg, setting tank 18 in. above floor level. (Weight of plastic fat when tank is full is 190,000 pounds.)

Price f.o.b. factory $12,300

Partially Hydrogenated Cottonseed Oil Storage and Transport Pump, 50 g.p.m., carbon steel and/or 316 SS, to pump partially hydrogenated cottonseed oil (I.V. 70), which is a plastic fat containing less than 12 percent solids, from tank car into storage tank or from storage tank into surge tank, 50 ft. dynamic head. The plastic fat is at 85°F, has a specific gravity of 0.91 and a viscosity of 60 cp. Equal to Robbins and Myers Moyno Pump Frame 1L8 Type CSQ (progressing cavity positive displacement pump) constructed with cast iron suction housing,

316 SS rotor and shaft with hard chrome plating over the rotor and shaft at the stuffing box area, and Buna N stator. Unit complete with fabricated steel base, V-belt drive (for pump speed of 470 r.p.m.), OSHA belt guard and 3 HP, 1800 r.p.m. TEFC motor 230/460/3/60.

Price f.o.b. factory $ 2,237

Crude Esters Storage Tank, 33,000 gallons, 304 SS, 3/8 in. plate, 14 ft. diameter x 28 ft. vertical tank (along the straight side), coned bottom. Equipped with 8 in. welding neck flange to receive side entering agitator; a 1 1/2 in. diameter x 300 ft. spiral-helical low-pressure steam coil at bottom to enable increasing temperature for easier pumping of crude esters from the tank; 20 in. manhole; 4 - 4 in. couplings at or near the top; 4 in. coupling at the bottom; 5 - 1 in. couplings on side wall for liquid level indicators; with 6 - 6 in. x 6 in. x 3/8 in. steel angle legs, 62 in. long, welded to tank with at least 12 in. of 3/8 in. weld each leg, setting tank 18 in. above floor level. (Weight of liquid when tank is full is 306,000 pounds.)

Price f.o.b. factory $46,800

Mixer for Crude Esters Storage Tank, for intermittent use along with heating coil to discourage freezing of crude esters. Temperature of esters can range from 70°F to 374°F (temperature at which esters are to be pumped into the tank from the reactor). Specific gravity is 1.112. At 70°F, viscosity of crude esters is about equal to that of SAE 90 lubricating oil at atmospheric temperature. (SAE 90 has viscosity of approximately 285 cs. at 100°F.) At 374°F, viscosity of crude esters is about equal to that of SAE 40 lubricating oil at atmospheric temperature. Equal to Model 108RSES10 Lightnin gear driven, side entering agitator, complete with single mechanical seal, and installed on an 8 in. ASA 150 lb. mounting flange. Includes 10 HP TEFC motor.

Price f.o.b. factory $ 3,800

Crude Esters Pump is listed under "III. Crude Esters Process Equipment".

Total price, "IV. Raw Materials and Product Storage Equipment," f.o.b. factory excluding freight and taxes $84,571

V. SERVICE FACILITIES

A. HEAT TRANSFER LIQUID SYSTEM

The heat transfer liquid system supplies at least 10.33 MM B.T.U. to each 12-ton batch of crude glycerol glucoside esters. Heat transfer occurs at the half-pipe coil jacket of the reactor during the entire production cycle (4 hrs. 40 min.), and in the auxiliary heat exchanger after addition of partially hydrogenated cottonseed oil and sodium soaps during interesterification. Mobil Oil Corporation's Mobiltherm 603, Monsanto's Therminol 55, Dow Chemical Company's Dowthern G, or equal low pressure heating media can be used. Heat storage requirements preclude use of 400 p.s.i. hot water.

Heat is supplied as follows (refer to Figure 1, "Batch Production of Crude Glycerol Glucoside Esters" on p. 13).

Heat Supplied To:	Total B.T.U.	Time, min.	Heating Rate B.T.U./min.	Heating Rate B.T.U./hr.
Heat $C_3H_8O_3$ from 70°F to 257°F (21.1°C to 125°C)	1,757,560			
Heat conc. H_2SO_4 from 70°F to 257°F	4,785			
Subtotal	1,762,345	40	44,059	2,643,518
Heat cornstarch from 70°F to 257°F	668,278	20	33,414	2,004,834
Heat Na_2CO_3 from 70°F to 257°F	3,651	5	730.2	43,812
Heat reaction mixture after addition of partially hydrogenated cottonseed oil and Na soaps. Includes heating mixture from 91.4°C to 190°C (196.5°F to 374°F), with evaporation of water of neutralization at 100°C (212°F), fusion of partially hydrogenated cottonseed oil, and solution of soap in oil. (Heats of reaction of starch and glycerol, and of interesterification are only slightly endothermic under process conditions and are disregarded.)	4,007,796	40	100,195	6,011,694
Distill glycerol	3,887,271	80	48,591	2,915,453
Total	10,329,341 B.T.U. per batch (excludes heat losses)			

From this tabulation it can be seen that maximum heating load occurs during the 40 minute period while heating the entire batch from 196.5°F to 374°F. On the basis of laboratory data, this can vary from 6,011,694 B.T.U./hr., as shown, to 7,070,250/B.T.U./hr.

The heat transfer liquid system should be equal to that tentatively designed and proposed for the process by American Hydrotherm Corporation, and consists of their Thermal Liquid Heater Model 1200-D4, capable of delivering 12 MM B.T.U./hr., burning either natural gas or No. 2 fuel oil at 70-80 percent efficiency, equipped with 15 HP blower drive motor; circulating pump with 30 HP motor packaged with the heater; a second pump at the reactor, with 40 HP motor to circulate heat transfer liquid through the reactor jacket and auxiliary heat exchanger; expansion tank with accessories; a small make-up pump; automatic control valves for temperature control; and valves for isolating heat transfer liquid equipment. Also includes pre-assembled control panel for the reactor with a programmer and recording controllers for both the batch temperature and jacket temperature.

The proposed heat transfer liquid system has a holding capacity of only approximately 2,000 gallons, made possible by reheating a relatively small amount of heat transfer liquid to 600°F in the heater and blending it with larger amounts of heat transfer liquid returning from the reactor and auxiliary heat exchanger. The blend of heat transfer liquid enters the reactor jacket and auxiliary exchanger jacket at 450°F and drops to 425°F before exiting the jackets. The maximum heating load including losses has been evaluated by the supplier to average 8.9 MM B.T.U./hr. during the 40-minute period that the entire batch is heated from 196.5°F to 374°F. The heater has been oversized to 12 MM B.T.U./hr. to reduce the size of the auxiliary heat exchanger, and, since the available temperature difference for heat exchange will be limited by the charring point of the batch (428°F), to be able to place more than average heat into the process at lower temperatures to compensate for the drop-off in heat transfer as the temperature difference between transfer liquid and reaction mixture decreases. For outdoor

installation. Overall dimensions of packaged liquid heater including circulating pump, make-up pump, and automatic control valves are 35 ft. 9 in. long x 7 ft. 4 in. wide x 9 ft. high. (Auxiliary heat exchanger is listed and priced separately under "III. Crude Esters Process Equipment (Including Glycerol Recovery)".)

Price f.o.b. factory excluding freight and taxes	$106,500
Price of 2,000 gallons of Mobiltherm 603	2,460
Total price, "V. A. Heat Transfer Liquid System", f.o.b. factory excluding freight and taxes (except for initial charge of heat transfer liquid which is delivered price).	$108,960

B. NITROGEN GENERATING SYSTEM

The nitrogen generating system supplies nitrogen gas

(1) to the dry starch bin, in order to maintain the moisture level of the dry cornstarch at one percent or less, until the starch is discharged into the reactor, usually within 24 hours, and

(2) to the reactor, to minimize oxidation of glycerol and fat. A N_2 blanket is maintained throughout the reaction cycle with the exception of the glycerol distillation interval, when almost complete vacuum is imposed.

Nitrogen Generating System, complete with inert gas generator, compressor, and molecular sieve system, for generating 2,000 standard cu. ft./hr. of N_2; for blanketing contents of 350 cu. ft. dry starch bin and 735 cu. ft. glycerol glucoside esters reactor; both bin and reactor operating at 1 atmosphere absolute pressure. Dry cornstarch bin is at ambient temperature, and contents of reactor reach temperature of 374°F. Nitrogen generating system is to be located in a separate enclosure away from the process building.

Equal to Kemp Creative Engineering Model MSA-2 Nitrogen Gas Generating System which includes:

(1) Kemp Model PH Inert Gas Generator (combustion chamber) with Kemp Nozzle Mix Combustion System, programmed automatic starting, and ASME designed shell and tube heat exchanger for indirectly cooling products of combustion. Generator automatically turns down to 30 percent of rated capacity when compressor is unloaded. Safety controls in accordance with FM Insurance Underwriters' requirements, and NEMA-1 electrical enclosures. Air blower with 5 HP motor.

(2) Compressor System, including heavy duty, water cooled, nonlubricated reciprocating compressor with V-belt drive, belts, enclosed belt guard and 20 HP motor. Compressor controls include constant speed control and electropneumatic unloading for efficient compressor operation. The inert gas generator responds by throttling its output from full demand to the turn down rate.

(3) Molecular Sieve Adsorption System to include dual adsorbing and dual ultrasorbing desiccant bed towers with automatic regeneration cycle. The adsorber removes the larger quantities of carbon dioxide and water vapor contained in the inert gas. The ultrasorber provides final purification of the

nitrogen gas and the ultra high purity nitrogen purge for regeneration of the adsorber. Dual towers are provided for continuous service. While one tower is on stream the other tower is regenerating.

(4) Nitrogen Receiver, 48 in. dia. x 13 ft. 9 in. high, 150 cu. ft. actual capacity, 850 cu. ft. max. usuable N_2 storage at 85 p.s.i.g., which is standard N_2 pressure at the receiver. With 2 pressure regulators for reducing pressure of gas to users to 1 p.s.i.g. N_2 temperature is less than $15^{o}F$ above cooling water temperature of $85^{o}F$.

Composition of N_2:

CO_2	20 ppm
CO	0.1-0.5 percent
H_2	0.1-0.5 percent
O_2	120 ppm (max.)
H_2O	Dewpoint,$-80^{o}F$ at 85 p.s.i.g.
N_2 & A	Balance

Utilities consumption at nominal rated capacity:

Fuel Gas:	426 standard cu. ft./hr. at 5-10 p.s.i.g.
Water:	30 g.p.m. at $85^{o}F$ ($30^{o}F$ temp. rise)
Electricity:	18 kw.

Approximate dimensions:

17 ft. 9 in. long x 11 ft. 6 in. wide x 8 ft. 6 in. high

Price f.o.b. factory excluding freight and taxes $40,075

Steam Boiler, equal to ABCO Model 250 AMC-FDG-300 PSI Boiler/ Burner package. Boiler is 300 p.s.i.g. A.S.M.E. code design with all controls for operating at 250 p.s.i.g. Boiler is rated at 250 boiler HP and has 5 sq. ft. of heating surface per boiler HP. Two-pass dry-back construction. Flame observation ports in front and rear, furnace access doors, handholes and manholes as per A.S.M.E. code, lifting lugs, steel jacket with 3 in. insulation compacted to 2 in., structural steel skids, A.S.M.E. safety valves, low water cutoff and pump controls with tricocks and sight glass. Burner is ABCO Model CB 250 force draft burner and controls with multijet annular ring drilled port burner, blower, 5 HP motor and starters, refractory cone, air interlock switch, automatic pilot with electric ignition, UV scanner, R4150 programmer with modulating butterfly and electric gas valve with automatic controller, pilot solenoid valve, main gas pressure regulator hand cock, NEMA 1 control cabinet with power-on and burner-on switches and lights. Complete unit assembled and test fired prior to shipment with copies of test report furnished. Overall dimensions: 202 in. long x 73 in. wide and 103 in. high.

Price f.o.b. factory	$25,372.50

Boiler Feed Water System, equal to ABCO Model 250 RSS, 300 lbs./sq. in. gage design feed water system, 350 gallons, complete with boiler feed pump, 20 HP motor, base, condensate return stand and frame, gage fixtures, make-up valve, strainer and piping, no feed water valve, with preheater including steam temperature regulator valves, steam trap, perforated tubes installed in return system. Overall dimensions: 72 in. long x 38 in. wide x 83 in. high.

Price f.o.b. factory	$ 3,343
Total price, "V. C. Steam Boiler and Accessories," f.o.b. factory excluding freight and taxes	$28,715

D. COOLING TOWER AND ACCESSORIES

The cooling tower supplies 41,476 gallons of 85°F water to process each 12-ton batch of crude glycerol glucoside esters as follows:

Cooling tower water supplied to:	Time, min.	Rate, g.p.m.	Total, gals./batch
Glycerol condenser	110	166.4	18,304
Glycerol aftercooler	110	78.2	8,602
Steam ejector intercondensers and aftercondenser	110	37	4,070
Nitrogen generator heat exchanger and compressor	350	30	10,500
		311.6	41,476

Cooling tower, 200 tons, for cooling 311.6 g.p.m. water from 120°F to 85°F at 80°F wet bulb. Equal to Baltimore Aircoil Company, Inc. Model VLT-200-B. Water make-up approximately 12 g.p.m. (3 g.p.m./100 tons for evaporative effect, and 3 g.p.m./100 tons for "bleed" purposes). 20 HP, 1750 r.p.m. dripproof ball-bearing fan motor suitable for outdoor service on 3 phase, 60 hertz, 220/440 volt electrical service. Overall dimensions: 12 ft. x 5 ft. with an overall height not exceeding 10 ft. All steel components made from hot-dip galvanized steel, with a final coating of zinc-chromatized aluminum.

Price, freight prepaid and allowed $ 5,818

Cooling tower accessories, for 200-ton tower, includes 311.6 g.p.m. centrifugal circulating pump, 40 ft. dynamic head, with 7 1/2 HP totally enclosed fan cooled motor; and two 175 g.p.m. tower pumps, centrifugal type, 15 ft. dynamic head, each with 2 HP totally enclosed fan cooled motor.

Price, freight prepaid and allowed $ 6,351

Total price, "V. D. Cooling Tower and Accessories," freight prepaid and allowed excluding taxes $12,169

Total price, "V. A., V. B., V. C., and V. D." $189,919

E. OFFSITE ELECTRIC DISTRIBUTION SYSTEM

For offsite transformation and distribution of power as required for operation of the hypothetical plant. This includes 3 phase, 60 hertz, 220/440 volt power distribution from supply source:

(1) Up to the physical limits of the process units, namely, the cornstarch receiving, storage, drying, and transfer equipment; sodium soaps receiving, storage, and transfer equipment; and crude esters process equipment (The process building defines the limits of the process units, or onsite facilities, with the exception of the onsite cornstarch receiving and storage equipment which is outdoors and near the building.);

(2) To such offsite support facilities as the heat transfer liquid system, nitrogen generator, steam boiler, and cooling tower; and

(3) To pumps and mixers in the storage tank area.

Electric Consumption

Equipment	Rated HP	Running time per batch (hrs.)	HP - hrs. per batch	Peak[1/] demand HP
Starch Unload and Storage				
Blower package	50	0.367	18.35	--
Rotary airlock	1	0.367	.37	--
Bin top filter separator	3	0.367	1.10	--
Rail car blower	7 1/2	0.367	2.75	--
Starch Transfer				
Storage bin activator	5	0.437	2.19	5
Blower package	30	0.437	13.11	30
Rotary airlock	1	0.437	0.44	1
Starch Drying				
Dryer feeder	1	4-1/3	4.33	1
Rotary airlocks (2)	1	4-1/3	4.33	1
Exhaust fan	25	4-1/3	108.25	25
Recycle fan	15	4-1/3	64.95	15
Starch to Reactor				
Dry starch bin activator	1 1/2	1/3	0.50	--
Rotary airlock	1 1/2	1/3	0.50	--
Reactor				
Agitator	20	6 1/2	130.00	20

Soaps Transfer				
Soaps feeder	1 1/2	1/10	0.15	1 1/2
Soaps bin activator	1 1/2	1/6	0.25	1 1/2
Mixers				
Glycerol storage tank	3	1/2	1.50	--
Crude esters storage tank	10	11/15	7.33	--
Glycerol holding tank	5	1/2	2.50	--
Process Pumps				
Glycerol storage pump	5	1/3	1.67	--
Glycerol pump	5	1/2	2.50	--
Recovered glycerol pump	5	1/2	2.50	--
Glycerol-water pump	2	1/4	0.50	--
Reactor pump	15	1 1/2	22.50	--
Partially hydrogenated cottonseed oil pump	15	1/12	1.25	15
Partially hydrogenated cottonseed oil storage and transport pump	3	1	3.00	--
Crude esters pump	7 1/2	1	7.50	--
Heat Transfer Liquid System				
Circulating pump at heater	30	4 1/2	108.00	30
2nd pump at reactor	40	4 1/2	144.00	40
Blower drive motor	15	3	45.00	15
Steam Boiler and Accessories				
Boiler blower	5	5.56	27.80	5
Feedwater pump	20	5.56	111.20	20
Nitrogen Generating System	25	5 5/6	145.80	25
Cooling Tower and Accessories				
Fan motor	20	5 5/6	116.67	20
2 tower pump motors	4	5 5/6	23.33	4
Main circulating pump	7 1/2	5 5/6	43.75	7 1/2
Totals			1169.87	282 1/2 or 210.6 kw.

1/ Peak demand occurs during addition of partially hydrogenated cottonseed oil and soaps to reactor

Estimated Cost, installed. $ 33,130

LIST OF EQUIPMENT SUPPLIERS*

Index

* The products of manufacturers listed are not recommended by the U.S. Department of Agriculture over those of other manufacturers. The names are provided for information purposes only.

Agitators

Chemineer Agitators
A division of Chemineer, Inc.
P. O. Box 1123
5870 Poe Avenue
Dayton, Ohio 45401
(Representative--Chem-Quip Inc.
P. O. Box 66504
Baton Rouge, La. 70806)

Cleveland Mixer Corp.
26061 Cannon Road
Bedford, Ohio 44146
(Representative--McLellan Division
Burgess Power Equipment
2375 Tchoupitoulas Street
New Orleans, La. 70150)

Lightnin Mixers and Aerators
Mixing Equipment Co., Inc.
115 Mt. Read Blvd.
Rochester, N. Y. 14603
(Representative--Gelatt Equipment Co., Inc.
1821 Wooddale Court
P. O. Box 15693
Baton Rouge, La. 70815)

Mix Mor, Inc.
3131 Casitas Avenue
Los Angeles, Calif. 90039
(Representative--Cron Chemical Corp.
P. O. Box 14042
Houston, Texas 77021)

Philadelphia Mixers Corp.
King of Prussia, Pa. 19406

ProQuip, Inc.
210 Hayes Drive
Cleveland, Ohio 44131
(Representative--Gulf States Engineering Co., Inc.
252 Harbor Circle
New Orleans, La. 70126)

Bins, Portable

The Powell Pressed Steel Co.
500 Erie Avenue
Hubbard, Ohio 44425
(Representative--Allied Equipment Sales, Inc.
1602 Tchoupitoulas Street
P. O. Box 53251
New Orleans, La. 70153)

Tote Systems Division
Hoover Ball and Bearing Co.
P. O. Box 456
Beatrice, Nebr. 68310
(Representative--Process Equipment Co.
501 North Jefferson Davis Pkwy.
New Orleans, La. 70119)

Bin Tilt Stations

Tote Systems Division
Hoover Ball and Bearing Co.
P. O. Box 456
Beatrice, Nebr.
(Representative--Process Equipment Co.
501 North Jefferson Davis Pkwy.
New Orleans, La. 70119)

Collector-Separators (for flash dryers)

Aerodyne Development Corp.
29085 Solon Road
Cleveland, Ohio 44139

Cooling Towers

Baltimore Aircoil Co., Inc.
Subsidiary of Merck and Co., Inc.
P. O. Box 7322
Baltimore, Md. 21227
(Representative--Lavigne Associates
701 Papworth--Suite 201
P. O. Box 9128
Metairie, La. 70055)

Binks Manufacturing Co.
9201 West Belmont Avenue
Franklin Park, Ill. 60131

P. O. Box 66090
Chicago, Ill. 60666

Cooling Towers (cont'd.)

The Ceilcote Co.
140 Sheldon Rd.
Berea, Ohio 44017
(Representative--Robert L. Rowan and Associates
P. O. Box 53395
New Orleans, La. 70153)

Lilie-Hoffman Cooling Towers, Inc.
186 E. Kirkham
St. Louis, Mo. 63119
(Representative--Devlin and Alpaugh, Inc.
4410 Calliope St.
P. O. Box 13428
New Orleans, La. 70185)

E. D. Goodfellow Co., Inc.
415 East Brooks Rd.
Memphis, Tenn. 38109
(Representative--Enochs Sales Co., Inc.
705 Camp Street
New Orleans, La. 70130)

Cornstarch Unloading, Storage, and Transfer Systems

Complete Systems

Boothe Engineering Co.
Division of Boothe Industries, Inc.
Airport Industrial Park
455 Cayuga Road
Cheektowaga, N. Y. 14225
(Representative--Martin and Company
2700 Highway 280 South
Birmingham, Ala. 35243)

Buhler-Miag, Inc.
8925 Wayzata Blvd.
Minneapolis, Minn. 55426

Butler Manufacturing Co.
Bulk Handling and Storage Division
BMA Tower, Penn Valley Park
P. O. Box 917
Kansas City, Mo. 64141

CEA Carter-Day Co.
500 Seventy-third Ave., N. E.
Minneapolis, Minn. 55432

Cornstarch Unloading, Storage, and Transfer Systems (cont'd.)

Complete Systems (cont'd.)

Chicago Conveyor Corporation
105 West Fay Avenue
Addison, Ill. 60101
(Representative--F. E. Warren Co., Inc.
7302 Tall Pines Drive
Houston, Texas 77088)

Consolidated Engineering Co.
2515 Morse
Houston, Texas 77019

Fluidizer, Inc.
General Resource Corp.
201 South Third Street
Hopkins, Minn. 55343

Mercer Engineers, Inc.
P. O. Box 15723
4251 Rhoda Drive
Baton Rouge, La. 70815

P. O. Box 22576
Houston, Texas 77027

Sprout, Waldron and Co., Inc.
Muncy, Pa. 17756

Systems and Applications Engineering Co.
Box 2102
Cedar Rapids, Ia. 52406

Service Engineering Co.
1001 South Dupre Street
P. O. Box 53009
New Orleans, La. 70153
(SEMCO, Inc.)

The Young Industries, Inc.
Muncy, Pa. 17756

Bins

Baughman-Oster Inc.
8123 Delmar Blvd.
St. Louis, Mo. 63130

Bin Activators

Vibra Screw Inc.
755 Union Blvd.
Totowa, N. J. 07512
(Representative--Mercer Engineers, Inc.
P. O. Box 15723
4251 Rhoda Drive
Baton Rouge, La. 70815

P. O. Box 22576
Houston, Texas 77027)

Epoxy Coatings for Starch System

Cargill Chemical Products Division
Cargill, Inc.
Cargill Building
Minneapolis, Minn. 55402

Columbia Paint Corp.
641 Jackson Avenue
P. O. Box 2888
Huntington, W. Va. 25728

E. I. DuPont deNemours & Co., Inc.
Fabrics and Finishes Department
308 East Lancaster Avenue
Wynnewood, Pa. 19096

Feeders, Volumetric

Vibra Screw Inc.
755 Union Blvd.
Totowa, N. J. 07512
(Representative--Mercer Engineers, Inc.
P. O. Box 15723
4251 Rhoda Drive
Baton Rouge, La. 70815

P. O. Box 22576
Houston, Texas 77027)

Feeders, Weigh

Merrick Scale Manufacturing Co.
180 Autumn Street
Passaic, N. J. 07055
(Representative--Koelling and Associates, Inc.
4101 San Jacinto
Houston, Texas 77004)

Feeders, Weigh (cont'd.)

Thayer Scale
Hyer Industries, Inc.
Pembroke, Mass. 02359
(Representative--Jim Ware Co.
P. O. Box 15411
Baton Rouge, La. 70815)

Solids Flow Transmitter

Yarway Corp.
Dept. SFT-2
Blue Bell, Pa. 19422

Cranes

Cleveland Tramrail Division
Cleveland Crane and Engineering
(Representative--Allied Equipment Sales, Inc.
P. O. Box 53251
New Orleans, La. 70153)

Dryers, Continuous

Convection--Direct Heat

Flash

Anhydro, Inc.
130 South Washington St.
North Attleboro, Mass. 02760

Komline-Sanderson Engineering Corp.
Peapack, New Jersey 07977
(Representative--POW Equipment, Inc.
7379 Ashcroft
Houston, Texas 77036)

Niro Atomizer, Inc.
American City Bldg.
P. O. Box 914
Columbia, Md. 21044
(Representative--George W. Faison
P. O. Box 8188
Houston, Texas 77004)

Dryers, Continuous (cont'd.)

Convection--Direct Heat (cont'd.)

Flash

Raymond/Bartlett-Snow
Combustion Engineering, Inc.
200 West Monroe Street
Chicago, Ill. 60606
(Area Sales Office--3334 Richmond Ave.
Houston, Texas 77006)

Rotating-Shelf (Vertical Moving Bed)

Wyssmont Company, Inc.
1470 Bergen Blvd.
Fort Lee, N. J. 07024
(Representative--Solids Industrial Equipment, Inc.
6006 Bellaire Blvd., #118
Houston, Texas 77036)

Conduction--Indirect Heat

Horizontal, Countercurrent

Rotary

FMC Corp.
Link-Belt Material Handling Systems Div.
Colmar, Pa. 18915
(Representative--William J. Preston
6001 Gulf Freeway, Suite C-150
Houston, Texas 77023)

Rotary Disc

The Strong-Scott Mfg. Co.
Berwind Process Equipment Group
333 N. E. Taft Street
Minneapolis, Minn. 55413

Thin Film

Luwa Corp.
P. O. Box 8009
Charlotte, N. C. 28208

Dryers, Continuous (cont'd.)

Twin Screw, Hollow Flight

Joy Manufacturing Co.
Denver Equipment Division
P. O. Box 5268
Denver, Colo. 80217
(Representative--Meldon Associates, Inc.
1249-A Blalock
Houston, Texas 77055)

Elevators, Freight

Otis Elevator Company
733 St. Joseph St.
New Orleans, La. 70130

P. O. Box 52679
New Orleans, La. 70152

Fork Lift Trucks

Otis Material Handling
Otis Elevator Co.
(Representative--Allied Equipment Sales, Inc.
P. O. Box 53251
New Orleans, La. 70153)

Heat Exchangers

American Heat Reclaiming Corp.
1270 Avenue of the Americas
New York, N. Y. 10020
(Representative--McCurnin, Swan and Associates, Inc.
P. O. Box 73208
Metairie, La. 70033)

American-Standard Power and Controls Group
Heat Transfer Division
175 Standard Pkwy.
Buffalo, N. Y. 14227
(Representative--John B. Elstrott
P. O. Box 24040
New Orleans, La. 70184)

Doyle and Roth Manufacturing Co., Inc.
One Broadway
New York, N. Y. 10004
(Representative--Process Equipment Co.
501 N. Jefferson Davis Pkwy.
New Orleans, La. 70119)

Heat Exchangers (cont'd.)

Graham Manufacturing Co., Inc.
170 Great Neck Road
Great Neck, N. Y. 11021
(Representative--The Cross Company, Inc.
4207 Rhoda Drive
Baton Rouge, La. 70816)

The Pfaudler Co.
Division of Sybron Corp.
P. O. Box 1600
Rochester, N. Y. 14603

Heat Transfer Liquid Systems

Complete Systems

American Hydrotherm Corp.
Industrial Division
470 Park Ave., South
New York, N. Y. 10016

Black Sivalls and Bryson, Inc.
4242 Southwest Freeway
P. O. Box 27125
Houston, Texas 77027

CE Natco (National Tank Co.)
1700 Destrehan Avenue
Harvey, La. 70058

Eclipse Lookout Co.
A Division of Eclipse, Inc.
P. O. Box 4756
Chattanooga, Tenn. 37405

Fulton Thermal Corp.
Jefferson Street
Pulaski, N. Y. 13142

Charles E. Sech Associates, Inc.
Consulting and Design Engineers
206 South Main Street
Ann Arbor, Mich. 48108

Heat Transfer Liquids

Dowtherm G

Dow Chemical U.S.A.
Barstow Building
2020 Dow Center
Midland, Mich. 48640

Dow Chemical U.S.A.
3636 Richmond Avenue
Houston, Texas 77027

Mobiltherm 603

Mobil Oil Corp.
North American Division
150 East 42nd Street
New York, N. Y. 10017

Houston Commercial Div.
P. O. Box 1740
Houston, Texas 77001

Therminol 55

Monsanto Industrial Chemicals Co.
800 N. Lindbergh Blvd.
St. Louis, Mo. 63166

Monsanto Industrial Chemicals Co.
1301 Post Oak Tower
5051 Westheimer Rd.
Houston, Texas 77027

Hoists

Cleveland Tramrail Division
Cleveland Crane and Engineering
8676 E. 289th Street
Wickliffe, Ohio 44092
(Representative--Allied Equipment Sales, Inc.
1602 Tchoupitoulas Street
P. O. Box 53251
New Orleans, La. 70153)

Nitrogen Generating Systems

Demarkus Corp.
1210 East Ferry St.
Buffalo, N. Y. 14211

Gas Machinery Co.
Gas Atmospheres, Inc.
21945 Drake Road
Strongsville, Ohio 44136

The C. M. Kemp Manufacturing Co.
Glen Burnie, Md. 21061
(Representative--J. T. Thorpe Co.
3030 I-10 Service Road
Suite B-2
Metairie, La. 70001)

Sunbeam Equipment Corp.
Subsidiary of Sunbeam Corp.
180-45 Mercer St.
Meadville, Pa. 16335

Superior Air Products Co.
2001 Jernee Mill Rd.
Sayreville, N. J. 08872

Surface Combustion Division
Midland-Ross Corp.
2375 Dorr Street
Toledo, Ohio 43691

Pumps

Goulds Pumps, Inc.
Seneca Falls, N. Y. 13148

Goulds Pumps, Inc.
8506 Airway Dr.
P. O. Box 15809
Baton Rouge, La. 70815

Midland-Bornemann Progressive Cavity Pumps
LFE Corp.
Fluids Control Division
100 Skiff Street
Hamden, Conn. 06514
(Representative--Flow-Quip, Inc.
P. O. Box 68
Kenner, La. 70062)

Pumps (cont'd.)

Moyno Pump Division
Robbins and Myers, Inc.
Springfield, Ohio 45501
(Representative--McCurnin, Swan and Associates, Inc.
P. O. Box 73208
Metairie, La. 70033)

Viking Pump Division
Houdaille Industries, Inc.
Cedar Falls, Iowa 50613
(Representative--Menge Pump and Machinery Co., Inc.
2740 North Arnoult Road
Metairie, La. 70002)

Reactors

Alloy Crafts Co.
Subsidiary of Lox Equipment Co.
P. O. Box 198
Delphi, Indiana 46923

Brighton Corporation
11861 Mosteller Road
Cincinnati, Ohio 45241

Chemical Equipment Corporation
4101 South New Haven Avenue
Tulsa, Okla. 74135

Patterson Industries
1250 St. George Street
East Liverpool, Ohio 43920
(Representative--Mercer Engineers, Inc.
P. O. Box 15723
4251 Rhoda Drive
Baton Rouge, La. 70815)

Tranter, Inc.
Panhandle Division
Lansing, Mich. 48909
(Western Sales---Thomas W. Manchester
P. O. Box 2289
Wichita Falls, Texas 76307)
(Louisiana Repr.-Alford, Woods and Childs, Inc.
11440 Darryl Drive
Baton Rouge, La. 70815)

Steam Boilers

ABCO Industries, Inc.
633 Walnut Street
Abilene, Texas 79604
(Representative--Forney Fuller and Associates, Inc.
1900 Veterans Mem. Blvd.
Metairie, La. 70005)

Clayton Manufacturing Co.
4213 North Temple City Blvd.
El Monte, Calif. 91731
(Representative--Carstone Corp.
321 Carondelet Bldg.
New Orleans, La. 70130)

Vapor Corp.
Va-Power Division
6420 West Howard St.
Chicago, Ill. 60648
(Representative--Aries Marine and Industrial Sales Corp.
4000 Haring Road
Metairie, La. 70002)

Steam Jet Ejectors

Ametek
Schutte and Koerting Division
Cornwells Heights, Pa. 19020
(Representative--R. W. Gildersleeve Co.
P. O. Box 66203
Baton Rouge, La. 70806)

Croll-Reynolds Co., Inc.
751 Central Avenue
Westfield, N. J. 07091
(Representative--Betz Engineering Sales Co.
P. O. Box 13248
New Orleans, La. 70125)

Graham Manufacturing Co., Inc.
170 Great Neck Road
Great Neck, N. Y. 11021
(Representative--The Cross Company, Inc.
4207 Rhoda Drive
Baton, Rouge, La. 70816)

Steam Jet Ejectors (cont'd.)

The Jet-Vac Corp.
73 Pond Street
Waltham, Mass. 02154
(Representative--Whelan and Associates
Box 13470/1701 Brun
Houston, Texas 77019)

Tanks

The Albach Co., Inc.
P. O. Box 1155
301 E. Prosper St.
Chalmette, La. 70043

I. C. M. Corp.
3540 River Road
Harvey, La. 70058

Industrial Tank Inc.
P. O. Box 1246
Chalmette, La. 70043

Schaller Steel Co., Inc.
11636 Old Gentilly Road
P. O. Box 26036
New Orleans, La. 70186

Welding and Manufacturing Co.
1040 South Peters Street
New Orleans, La. 70153

Dart Plastics
P. O. Box 1212
Metairie, La. 70004

6. FIXED CAPITAL INVESTMENT

(Refer to Tables I and II in this section)

Summary: Fixed capital investment for a grass roots plant for producing crude glycerol glucoside esters at the rate of twenty 12-ton batches monthly (the equivalent of operating only one 8-hour shift daily, 20 days per month) has been estimated to be $2.5 million. (Refer to the "All Systems" column in Table I.) For those who already have a reactor and the other process equipment for producing esters, including necessary service facilities, but have no starch equipment, fixed capital investment would be approximately one third of $2.5 million, or $815,200. (Refer to Table I, column headed "Cornstarch System Plus Its Proration of Service Facilities.")

Fixed capital investment for a grass roots plant for producing sixty 4-ton batches of product monthly (the equivalent of operating three 8-hour shifts daily, 20 days per month) has been estimated to be $1.9 million. This is approximately three fourths the fixed capital investment of the 12-ton batch plant, the reactor and immediately associated esters production facilities of the 4-ton batch plant being one third the size of comparable equipment in the larger plant. The starch system and all storage facilities would be the same size as in the larger plant since total production and bulk handling of raw materials and product would be the same in both plants.

Fixed capital investment (Table I) includes the following costs:

- Installed equipment cost
- Process piping
- Insulation
- Instrumentation and controls
- Electrical equipment and materials
- Service facilities
- Outside lines
- Buildings
- Land and yard improvements
- Engineering and supervision
- Construction
- Contingencies
- Contractor's fee

All process equipment costs, service facilities costs, and building costs were obtained within the past few months from scores of equipment manufacturers and building fabricators and their engineer representatives throughout the United States. (Refer to "List of Equipment Suppliers" on p. 50 at the end of "5. A Complete Equipment List with Specifications and Costs for Producing Crude Glycerol Glucoside Esters.")

Table I. Crude Glycerol Glucoside Esters of Fatty Acids
Fixed Capital Investment
Production Rate: 12 tons/day (240 tons/mo.)

Cost Item	All Systems Dols.	Corn-starch System[11] Dols.	Esters System[12] Dols.	Service Facil. Dols.	Proration of Service Facil. between: Corn-starch Dols.	Proration of Service Facil. between: Esters Dols.	Corn-starch System Plus its Proration of Service Facil. Dols.	Esters System Plus its Proration of Service Facil. Dols.
Direct Costs								
Purchased cost[1] of process equipment[2]	475,200	188,465	286,735				188,465	286,735
Installed cost of process equipment[2]	614,612	264,823	349,789				264,823	349,789
Process piping[3]	170,083	9,850	160,233				9,850	160,233
Insulation[4]	31,346	5,540	25,806				5,540	25,806
Instrumentation and controls[5]	24,728		24,728					24,728
Electrical equipment and materials	13/	13/	13/	13/	13/	13/	13/	13/
Service facilities								
N_2 generating system	51,937			51,937	38,953	12,984	38,953	12,984
Steam boiler and auxiliaries	47,190			47,190	33,071	14,119	33,071	14,119
Heat transfer liquid system	177,204			177,204	--	177,204	--	177,204
Cooling tower and auxiliaries	24,338			24,338	4,624	19,714	4,624	19,714
Electric substation	33,130			33,130	13,106	20,024	13,106	20,024
Subtotal service facilities	333,799			333,799	89,754	244,045	89,754	244,045
Outside lines[6]	30,731	13,241	17,490				13,241	17,490
Subtotal, direct equipment costs	1,205,299	293,454	578,046	333,799	89,754	244,045	383,208	822,091

Table I (continued)

Cost Item	All Systems Dols.	Corn-starch System[11] Dols.	Esters System[12] Dols.	Service Facil. Dols.	Proration of Service Facil. between Corn-starch Dols.	Proration of Service Facil. between Esters Dols.	Corn-starch System Plus its Proration of Service Facil. Dols.	Esters System Plus its Proration of Service Facil. Dols.
Buildings (Including services)								
Process building	503,938	178,375	325,563				178,375	325,56
Boiler house	2,255			2,255	1,580	675	1,580	67
N_2 generating system house	2,255			2,255	1,690	565	1,690	56
Land and yard improvements[7]	87,912	34,866	53,046				34,866	53,04
Direct costs	1,801,659	506,695	956,655	338,309	93,024	245,285	599,719	1,201,94
Indirect Costs								
Engineering and supervision[8]	173,013	50,669	95,666	26,678	5,533	21,145	56,202	116,81
Construction[8]	173,013	50,669	95,666	26,678	5,533	21,145	56,202	116,81
Contingencies[9]	239,335	70,092	132,338	36,905	7,654	29,251	77,746	161,58
Contractor's fee[10]	77,856	22,802	43,049	12,005	2,490	9,515	25,291	52,56
Indirect costs	663,217	194,232		102,266	21,210	81,056	215,441	447,77
Fixed capital investment (direct cost plus indirect costs)	2,464,876	700,927	1,323,374	440,575	114,234	326,341	815,160	1,649,71

FOOTNOTES FOR TABLE I

1/ Delivered price, includes state sales or use tax. Listed for information only. Not counted as such in totals.

2/ Includes motors.

3/ 16 percent of solids processing equipment cost plus 66 percent of fluids processing equipment cost.

4/ 9 percent of the sum of starch dryer system cost and esters system equipment cost.

5/ 13 percent of purchased (delivered) cost of selected equipment for which instrumentation and controls were not included in purchased cost.

6/ 5 percent of installed cost of process equipment.

7/ 18.5 percent of purchased (delivered) cost of process equipment.

8/ 10 percent of (direct costs less steam boiler and cooling tower costs). Costs of steam boiler and cooling tower already include indirect costs.

9/ 10 percent of (direct costs less steam boiler and cooling tower costs) plus 10 percent of indirect costs. Costs of steam boiler and cooling tower already include indirect costs.

10/ 4.5 percent of (direct costs less steam boiler and cooling tower costs). Costs of steam boiler and cooling tower already include indirect costs.

11/ Includes cornstarch receiving, storage, drying and transfer equipment. (Ref. "5. A Complete Equipment List with Specifications and Costs for Producing Glycerol Glucoside Esters, I. Cornstarch Receiving, Storage, Drying and Transfer Equipment," pp. 24-29.)

12/ Includes Na soaps receiving, storage and transfer equipment; crude esters process equipment including glycerol recovery; and raw materials and product storage equipment; that is, all process equipment with the exception of cornstarch receiving, storage, drying and transfer equipment. (Ref. "5. Complete Equipment List with Specifications and Costs for Producing Glycerol Glucoside Esters, II through IV," pp. 29-38.)

13/ Distributed among costs of process equipment, service facilities, outside lines, and buildings.

Table II. Crude Glycerol Glucoside Esters Plant

Installed Equipment Costs

Production Rate: 12 tons/day (240 tons/mo.)

	Price,[1/] f.o.b. factory, Dols.	Delivered, price,[2/] including state sales tax, Dols.	Installation factor, Percent of delivered cost	Installed cost[7/], Dols.
I. CORNSTARCH RECEIVING, STORAGE, DRYING, AND TRANSFER EQUIPMENT				
A. Rail car/truck unload and storage	56,850	61,398	40	85,957
B. Transfer	24,655	26,627	40	37,278
C. Dryer and accessories	69,000	74,520	50[6/]	105,300
D. Dry starch system	24,000	25,920	40	36,288
Subtotal I.	174,505	188,465		264,823
II. SODIUM SOAPS RECEIVING, STORAGE AND TRANSFER EQUIPMENT				
Portable bins	24,380	26,331	--	26,331
Gravity tilt station	3,300	3,564	40	4,990
Soaps holding bin	8,579	9,265	30	12,045
Soaps feeder	5,251	5,671	40	7,939
Subtotal II.	41,510	44,831		51,305
III. CRUDE ESTERS PROCESS EQUIPMENT				
Reactor	57,000	61,560	40	86,184
Reactor mixer	8,000	8,640	15	9,936
Auxiliary heat exchanger	19,627	21,197	20	25,436
Glycerol condenser	10,957	11,834	20	14,200

Table II (continued)

CRUDE ESTERS PROCESS EQUIPMENT (cont'd)	Price,[1] f.o.b. factory, Dols.	Delivered price,[2] including state sales tax, Dols.	Installation factor, Percent of delivered cost	Installed cost[7], Dols.
Glycerol aftercooler	10,065	10,870	20	13,044
Reactor pump	2,875	3,105	10	3,416
Steam jet ejector	12,500	13,500	12	15,120
Glycerol holding tank	5,090	5,497	15	6,322
Mixer for glycerol holding tank	3,000	3,240	15	3,726
Recovered glycerol pump	2,530	2,732	10	3,005
Glycerol-water pump	830	896	10	986
Partially hydrogenated cottonseed oil pump	3,800	4,104	15	4,720
Partially hydrogenated cottonseed oil holding tank	1,375	1,485	30	1,931
Crude esters pump	1,766	1,907	10	2,098
Subtotal III.	139,415	150,567		190,124
IV. RAW MATERIALS AND PRODUCT STORAGE EQUIPMENT				
Glycerol storage tank	11,400	12,312	15	14,159
Mixer for glycerol storage tank	3,234	3,493	15	4,017
Glycerol storage pump	2,400	2,592	15	2,981
Glycerol pump	2,400	2,592	15	2,981
Partially hydrogenated cottonseed oil storage tank	12,300	13,284	40	18,598

Table II (continued)

RAW MATERIALS AND PRODUCT STORAGE EQUIPMENT (cont'd)	Price,[1] f.o.b. factory, Dols.	Delivered price,[2] including state sales tax, Dols.	Installation factor, Percent of delivered cost	Installed cost[7], Dols.
Partially hydrogenated cottonseed oil storage and transport pump	2,237	2,416	15	2,778
Crude esters storage tank	46,800	50,544	15	58,126
Mixer for crude esters storage tank	3,800	4,104	15	4,720
Subtotal IV.	84,571	91,337		108,360
Subtotal I, II, III, and IV.	440,001	475,200		614,612
V. SERVICE FACILITIES				
A. Heat transfer liquid system				
Equipment	106,500	115,020	25	143,775
Heat transfer liquid	2,460	2,657	--	2,657
Subtotal V. A.	108,960	117,677		146,432
B. Nitrogen generating system	40,975	43,281	20	51,937
C. Steam boiler and accessories				
Boiler	25,372	26,833[3]		
Boiler feed water system	3,343	3,611		
Subtotal V. C.	28,715	30,444	22	37,142
D. Cooling tower and accessories				
Cooling tower	5,818[4]	5,993[5]		
Cooling tower accessories	6,351[4]	6,541[5]		
Subtotal V. D.	12,169[4]	12,534[5]	22	15,291
Subtotal V. A. through V. D.	189,919	203,936		250,802
Total I. through V. D.	629,920	679,136		865,414
E. Offsite electric distribution system				33,130[8]
Total I. through V. E.				898,544

FOOTNOTES FOR TABLE II.

1/ Excludes sales tax.

2/ Previous column plus 3 percent state sales tax and 5 percent for freight (equal to previous column x 1.08), unless otherwise indicated.

3/ Previous column plus 3 percent state sales tax and $700 for freight as per bid received.

4/ Freight prepaid and allowed.

5/ Previous column plus 3 percent state sales tax.

6/ The 50 percent installation factor cited is applicable to the delivered price of the dryer only, which is $61,560 of the $74,520 shown in the previous column. The remainder of the delivered price is for the explosion suppression system including its installation cost.

7/ Includes foundations, platforms and supports as required, and erection of equipment. Excludes process and service piping (except piping included in package units); instrumentation and controls other than that included in the price of equipment; vessel and pipe insulation; electrical service; and any other direct and indirect fixed capital investment costs.

8/ Exception to footnote 7. Includes all direct fixed capital investment costs.

Installed equipment costs for the 12-ton batch plant are summarized in Table II. They were estimated from f.o.b. factory prices in "5. A Complete Equipment List with Specifications and Costs for Producing Crude Glycerol Glucoside Esters" by adding 3 percent for state sales tax, 5 percent for shipping, and various percentages for foundations, structural platforms and supports, uncrating, and erection, as required. Motors and most of the instrumentation and controls are included in installed equipment costs.

Process Piping (Table I) refers to the pipe, valves, and fittings associated directly with the process equipment and storage tanks, including utility lines as well as lines carrying process materials. This portion of the piping is bounded by the area of the process building and the area of the storage tank aggregate. Costs of service piping within the building area but not associated with the process, such as steam for heating, and sanitary and drinking water, are included in building costs. Process piping is made up of chemical, N_2 gas, steam, heat transfer liquid, water, air, and product piping, and was calculated on the basis of 16 percent of the sum of purchased costs (delivered) of solids processing equipment (i.e., soaps handling equipment and starch dryer) plus 66 percent of the sum of purchased costs (delivered) of fluids processing equipment (i.e., all process equipment in the plant other than soaps and starch equipment). No process piping was estimated for the starch unloading, storage, and transfer systems because starch tubing is included as a part of equipment cost.

Insulation cost, including labor and materials for insulating equipment and piping, was calculated on the basis of 9 percent of the purchased cost (delivered) of all process equipment in the plant, including the starch dryer, but excluding the starch unloading, storage, and transfer systems for which no insulation is required.

Instrumentation and controls cost is additional to the cost of instrumentation and controls included in equipment cost. It was calculated on the basis of 13 percent of the purchased cost (delivered) of process equipment for which instrumentation and controls are not included in equipment costs, namely storage and holding tanks, heat exchangers, process pumps, the soaps feeder, and the steam jet ejector. In addition, 5 percent of the reactor cost was included to allow for instrumentation and

controls other than the temperature controls provided by the liquid heat transfer system manufacturer as part of a pre-assembled reactor control panel including a programmer and controlling temperature recorders for both batch and jacket. For instrumentation and controls provided with equipment, see "5. Complete Equipment List with Specifications and Costs for Producing Crude Glycerol Glucoside Esters," p. 23 ff.

Electrical equipment and materials cost, including labor, has been distributed among process equipment cost, service facilities, outside lines, and building costs. Motors, starters, and wiring for process equipment are included in installed equipment costs. Substation and transformer costs are a part of service facilities cost, outside feeder lines are included with costs of outside lines, and electrical services within buildings are included with building costs.

Service facilities costs include N_2 generating system, steam boiler and auxiliaries, heat transfer liquid system, cooling tower and auxiliaries, and electric substation. Complete descriptions with costs are given in "5. Complete Equipment List with Specifications and Costs for Producing Crude Glycerol Glucoside Esters," p. 39. Costs of service facilities have been prorated between the cornstarch system and the esters system (see Footnotes 11 and 12 of Table I) in proportion to the relative use of service facilities by these two systems. The proration has made possible separate determinations of fixed capital investment for the starch system and the esters system.

Outside lines, those not included in process piping costs and building costs, include all piping external to the building area and to the area of the storage tank aggregate. This category includes lines between the service facilities and the process building (i.e., steam, cooling water, heat transfer liquid, N_2 gas, and electric feeder lines); lines between the service facilities and the storage tank aggregate (i.e., steam and electric feeder lines); lines between the process building and the storage tank aggregate (i.e., glycerol, partially hydrogenated cottonseed oil, and crude esters piping); lines between the various service facilities (i.e., cooling water to N_2 generator, and electric feeder lines to each of the service facilities); and all drain lines external to the process building. Outside lines cost was calculated on the basis of 5 percent of installed process equipment cost and includes supports for overhead lines where required.

<u>Building costs</u> include the process building, boiler house, and N_2 generating system house. The only major building is the process building (mentioned under "4. Plant Layout", page 20, and shown in Figures 5 and 6). Process building cost includes the basic building, drain piping, skylights, roof ventilators, rolling doors, lighting, general plumbing, fire prevention, balconies, stairways, elevator, overhead traveling crane, and fork lift truck.

PROCESS BUILDING SPECIFICATIONS

(Refer to Figures 5 and 6, introduced under "4. Plant Layout," p. 20.)

<u>Dimensions</u>: 30 ft. wide by 135 ft. long by 62 ft. high.

<u>Construction</u>: Structural steel with covering of corrugated steel. Rigid frame with trusses located at 16 ft. intervals except for one end bay where trusses are 7 ft. apart. Roof slope is 1 in 12.

<u>Balconies</u>: Two balconies, each 112 ft. long by 20 ft. 9 in. wide, located at elevations of 23 ft. and 36 ft. above the concrete floor. Balconies are to have aluminum grating floors and aluminum railings.

<u>Foundations and Basement Floor</u>: One ft. of fill, concrete foundations consisting of 1 1/2 yds. of concrete for each column. Five-inch reinforced concrete floor having 6 in. by 6 in. No. 6 reinforced wire mesh and with a floor drain for every 150 sq. ft.

<u>Elevator shaft</u>: A 10,000 lb. capacity freight elevator with front and back openings, for industrial truck loading, will be provided by the owner. Hoistway with elevator machine room above, to be provided by building contractor, will rise to 24 ft. 8 in. above the second balcony level. Hoistway measures 11 ft. 4 in. wide by 13 ft. 4 in. deep and has six 8 ft. by 8 ft. openings, two at each of three levels (basement and two balcony levels). Pit extends to 5 ft. below the concrete floor.

<u>Stairways</u>: Metal stairways extending from the basement to both balconies, located as indicated by dashed lines on Figure 6.

Rolling Doors: Two power operated rolling doors, 12 ft. wide by 18 ft. high, one at each end of the building.

Other: Deluge sprinkler system and other fire prevention throughout the building; continuous roof ventilation system; 2 skylights per bay, lighting and plumbing.

The above structure exclusive of balconies, general plumbing, deluge sprinkler system and other fire prevention, elevator shaft and stairways, is to be equal to the Armco Building System recommended and estimated by Broadmoor Corporation, 3017 Kingman St., Metairie, La. 70002 on February 11, 1976. The balconies, general plumbing, deluge sprinkler system and other fire prevention, elevator shaft, and stairways were estimated by the Southern Regional Research Center.

Budgetary cost of complete process building excluding elevator, fork lift truck and crane which are listed separately below: $330,222

Elevator, freight, 10,000 lbs. capacity at 150 ft./min. speed; travel from basement to 2nd floor, about 36 ft.; 3 stops with 6 openings, 3 at the front and 3 at the back of the hoistway; generator field control with 2-way automatic self-leveling; single automatic push button operation; geared traction machine, located overhead; platform 8 ft. 4 in. wide by 12 ft. front to back; all steel construction, structural steel frame, solid metal sides, perforated metal top with hinged exit panel; instantaneous safety/spring buffers; 6 bi-parting, 8 ft. wide by 8 ft. high hoistway doors; power operation for hoistway doors and vertical lifting car gates; mechanical push type button signals for car and hall, car position indicator; explosion proof equipment suitable for Class I Group D Division 2 hazardous location, hoistway Class C3 freight loading; safety shoes device on vertical lifting car gate, special emergency service Phase No. 1; in accordance with American National Standard Safety Code for elevators. Equal to Otis Freight Elevator as offered by Sales Representative, New Orleans Area, Otis Elevator Co., 733 St. Joseph St., New Orleans, La., 70130, on February 25, 1976: $130,000.

<u>Fork lift truck</u>, 2000 lbs. capacity at 24 in. load center, 130 in. fork lift, 83 in. lowered mast height, 10 in. free lift. SCR controls, 24 volt electric system, explosion proof suitable for operation in Class I Group D Division 2 hazardous location. Equal to Otis Moto-Truc Electric Powered Rider Counterbalanced Fork Lift Truck Model CB-R-20/24 as offered by Allied Equipment Sales, Inc., P. O. Box 53251, New Orleans, La., 70153 on March 19, 1976: $14,369

<u>Lead acid battery</u>, for fork lift truck, 600 A. H. capacity, explosion proof label, equal to Gould Model 12-100X-13 EX, from same source as truck: $ 2,042

<u>Charger, battery</u>, standard automatic for charging above battery in 8 hours or less, equal to Gould Model GFC 12-600-1, 208/230/460 V, 3 phase, from same source as truck: $ 777

<u>Crane</u>, overhead, 10-ton capacity, spanning the width of the building (30 ft.), to move along two tracks for the entire length of the process building (135 ft.). Equipped for operation in Class I Group D Division 2 location. Built to Underwriters' Laboratories, Inc. specifications. 58 ft. 9 in. lift at 40 ft./min. 6 HP explosion proof motor, 4 button pendant, bronze block, bronzed hook, bronze wheels in trolleys, aluminum P. B. box; 2 part single, stainless steel cables; 50 ft. explosion proof cable reel; with sufficient track for 3 point suspension. Equal to P&H Electric Self Propelled Hoist by Cleveland Tramrail Division of Cleveland Crane and Engineering, represented by Allied Equipment Sales, Inc., P. O. Box 53251, New Orleans, La. 70153.

Installed cost as estimated at S.R.R.C.: $26,528

Budgetary cost of complete process building including elevator, fork lift truck and crane: $503,938

<u>Boiler house</u>, 20 ft. by 24 ft. by 15 ft. high, low cost garage-type structure, flat roof, concrete floor, spread footings, no services other than those for operating boiler: $ 2,255

<u>N_2 generating system house</u>, same as boiler house except no services other than those for operating N_2 generating system: $ 2,255

<u>Land and yard improvements</u> includes surveys and fees, property cost, and site development--site clearing, grading, roads, walkways, railroad siding, fences and parking area. Land was calculated on the basis of 6 percent of the purchased cost (delivered) of process equipment, and yard improvements on the basis of 12.5 percent of the purchased cost (delivered) of process equipment.

<u>Indirect plant costs</u>, namely engineering and supervision, construction expenses, contractor's fee, and contingencies have been estimated on the basis of percentages of direct plant costs that are considered to be fair average values. However, since the steam boiler and cooling tower costs already include indirect costs, their values were subtracted from direct plant costs before percentages were applied. In the case of contingencies, a percentage of indirect plant costs was included in addition to a percentage of direct plant costs. The percentages used are as follows: engineering and supervision, 10 percent of (direct costs less steam boiler and cooling tower costs); construction, 10 percent of (direct costs less steam boiler and cooling tower costs); contractor's fee, 4.5 percent of (direct costs less steam boiler and cooling tower costs); and contingencies, 10 percent of (direct costs less steam boiler and cooling tower costs) plus 10 percent of indirect costs.

7. MANUFACTURING COSTS AND GENERAL EXPENSES

(Refer to Tables III through V in this section)

SUMMARY: It has been estimated that it would cost 44.41 cents per pound to produce, distribute, and market crude glycerol glucoside esters when operating a new or partly depreciated plant at the rate of twenty 12-ton batches of product monthly (the equivalent of operating only one 8-hour shift daily, 20 days per month), if no other products are manufactured in the equipment when it is not in use for esters production. (Refer to the leftmost column of costs in Table III.) If other products are manufactured in the same equipment to the extent of 3-shift daily operations (or if esters production would increase to that extent) esters cost would decrease to 37.31 cents per pound. (Refer to 3d column of costs in Table III.) If fully depreciated equipment is available, esters cost would decrease to 36.61 cents per pound. (Refer to 6th column of costs in Table III.)

If the crude esters of a batch would be purified, and the glucosides thus recovered from the crude esters would be introduced into a subsequent batch at the completion of the reaction of fresh starch and glycerol in that batch, then raw materials and associated utilities costs would be reduced, thereby reducing total product cost almost 4 cents per pound. (Compare six columns of Table III that are headed "Production of crude esters from both fresh raw materials and recovered glycerol glucoside from purification of previous batch" with corresponding six columns headed "Production of crude esters entirely from fresh raw materials." Also refer to Raw Materials" on p. 86.)

It has also been estimated that it would cost 45.24 cents per pound to produce, distribute, and market crude glycerol glucoside esters when operating a new or partly depreciated plant at the rate of sixty 4-ton batches of product monthly (the equivalent of operating three 8-hour shifts daily, 20 days per month). This cost is 0.83 cent per pound more than the comparable 44.41 cents per pound cost for the 12-ton batch plant, and there would be little potential for reducing costs in the 4-ton batch plant since equipment would be in use full time for producing crude esters alone. Additional capacity and investment would be required for any increase in esters production beyond the current level. If fully depreciated equipment would be used, costs in the 4-ton batch plant would decrease approximately 2 cents per pound for crude glycerol glucoside esters.

Table III. Crude Glycerol Glucoside Esters of Fatty Acids

Manufacturing Costs and General Expenses

(Production Rate: 12 tons/day (240 tons/mo.)[1/]

Total Product Cost	Production of crude esters entirely from fresh raw materials						Production of crude esters from both fresh raw materials and recovered glycerol glucosides from purification of previous batch					
	New or partly depreciated plant			Depreciated plant			New or partly depreciated plant			Depreciated plant		
I. Manufacturing Costs A. Direct Production Costs	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch
(a) Raw materials												
Anhydrous $C_3H_8O_3$	1,617.87	1,617.87	1,617.87	1,617.87	1,617.87	1,617.87	1,034.30	1,034.30	1,034.30	1,034.30	1,034.30	1,034.30
Concentrated H_2SO_4 (93%)	3.96	3.96	3.96	3.96	3.96	3.96	2.60	2.60	2.60	2.60	2.60	2.60
Cornstarch (11.5% H_2O)	1,033.38	1,033.38	1,033.38	1,033.38	1,033.38	1,033.38	680.60	680.60	680.60	680.60	680.60	680.60
Na_2CO_3 (a. 58.5% Na_2O)	7.02	7.02	7.02	7.02	7.02	7.02	4.62	4.62	4.62	4.62	4.62	4.62
Partially hydrogenated cottonseed oil (I. V. 70)	3,340.29	3,340.29	3,340.29	3,340.29	3,340.29	3,340.29	3,181.37	3,181.37	3,181.37	3,181.37	3,181.37	3,181.37
Na soaps of cottonseed fatty acids	689.64	689.64	689.64	689.64	689.64	689.64	596.23	596.23	596.23	596.23	596.23	596.23
N_2 gas	2/	2/	2/	2/	2/	2/	2/	2/	2/	2/	2/	2/
(b) Operating labor	166.20	166.20	166.20	166.20	166.20	166.20	166.20	166.20	166.20	166.20	166.20	166.20
(c) Direct supervisory[3/] and clerical labor	24.93	24.93	24.93	24.93	24.93	24.93	24.93	24.93	24.93	24.93	24.93	24.93
(d) Maintenance and repairs[4/]	453.28	411.98	201.46	453.28	411.98	201.46	453.28	411.98	201.46	453.28	411.98	201.46

Table III. (continued)

Total Product Cost	Production of crude esters entirely from fresh raw materials						Production of crude esters from both fresh raw materials and recovered glycerol glucosides from purification of previous batch					
	New or partly depreciated plant			Depreciated plant			New or partly depreciated plant			Depreciated plant		
I. Manufacturing Costs (cont'd.) A. Direct Production Costs (cont'd.)	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch
(e) Operating supplies (15% of d)	67.99	61.80	30.22	67.99	61.80	30.22	67.99	61.80	30.22	67.99	61.80	30.22
(f) Utilities												
Electricity	27.30	17.64	15.17	27.30	17.64	15.17	26.75	16.91	14.72	26.75	16.91	14.72
Water	3.97	3.58	3.58	3.97	3.58	3.58	3.97	3.58	3.58	3.97	3.58	3.58
Steam	28.55	28.55	28.55	28.55	28.55	28.55	22.40	22.40	22.40	22.40	22.40	22.40
Natural gas	32.49	32.49	32.49	32.49	32.49	32.49	32.49	32.49	32.49	32.49	32.49	32.49
(g) Laboratory charges (15% of b)	24.93	24.93	24.93	24.93	24.93	24.93	24.93	24.93	24.93	24.93	24.93	24.93
(h) Subtotal, direct production costs (¢/lb.)[1/]	7,521.80 (31.41)	7,464.26 (31.17)	7,219.69 (30.15)	7,521.80 (31.41)	7,464.26 (31.17)	7,219.69 (30.15)	6,322.66 (27.72)	6,264.94 (27.47)	6,020.65 (26.40)	6,322.66 (27.72)	6,264.94 (27.47)	6,020.65 (26.40)

Table III. (continued)

Total Product Cost	Production of crude esters entirely from fresh raw materials						Production of crude esters from both fresh raw materials and recovered glycerol glucosides from purification of previous batch					
	New or partly depreciated plant			Depreciated plant			New or partly depreciated plant			Depreciated plant		
I. Manufacturing Costs (cont'd.)	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch
B. Fixed Charges												
(i) Depreciation[5]	459.97	390.36	153.32	--	--	--	459.97	390.36	153.32	--	--	--
(j) Property taxes[6]	251.82	224.29	83.94	251.82	224.29	83.94	251.82	224.29	83.94	251.82	224.29	83.94
(k) Insurance[7]	100.73	89.72	33.58	100.73	89.72	33.58	100.73	89.72	33.58	100.73	89.72	33.58
(l) Subtotal, fixed charges (¢/lb.)[1]	812.52 (3.39)	704.37 (2.94)	270.84 (1.13)	352.55 (1.47)	314.01 (1.31)	117.52 (0.49)	812.52 (3.56)	704.37 (3.09)	270.84 (1.19)	352.55 (1.55)	314.01 (1.38)	117.52 (0.52)
C. Plant overhead Costs[8]	386.65	361.87	235.55	386.65	361.87	235.55	386.65	361.87	235.55	386.65	361.87	235.55
(m) Subtotal, plant overhead costs (¢/lb.)[1]	386.65 (1.62)	361.87 (1.51)	235.55 (0.98)	386.65 (1.62)	361.87 (1.51)	235.55 (0.98)	386.65 (1.70)	361.87 (1.59)	235.55 (1.03)	386.65 (1.70)	361.87 (1.59)	235.55 (1.03)
(n) Total manufacturing costs[9] (¢/lb.)[1]	8,720.97 (36.42)	8,530.50 (35.62)	7,726.08 (32.26)	8,261.00 (34.50)	8,140.14 (33.99)	7,572.76 (31.62)	7,521.83 (32.98)	7,331.18 (32.15)	6,527.04 (28.62)	7,061.86 (30.97)	6,940.82 (30.44)	6,373.72 (27.95)

Table III. (continued)

Total Product Cost	Production of crude esters entirely from fresh raw materials						Production of crude esters from both fresh raw materials and recovered glycerol glucosides from purification of previous batch					
	New or partly depreciated plant			Depreciated plant			New or partly depreciated plant			Depreciated plant		
	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch	1-shift operation no sharing, $/batch	Sharing of service facilities, $/batch	Sharing of entire plant, $/batch
II. General Expenses												
(o) Administrative expenses 10/	83.10	83.10	83.10	83.10	83.10	83.10	83.10	83.10	83.10	83.10	83.10	83.10
(p) Distribution and marketing expense 11/	436.05	426.53	386.30	413.05	407.01	378.64	376.09	366.56	326.35	353.09	347.04	318.69
(q) Research and development expenses 12/	174.42	170.61	154.52	165.22	162.80	151.46	150.44	146.62	130.54	141.24	138.82	127.47
(r) Financing expenses 13/	1,219.46	1,114.98	585.12	1,205.60	1,103.22	580.50	1,174.39	1,069.90	540.05	1,160.53	1,058.15	535.43
(s) Subtotal, general expenses (¢/lb.) 1/	1,913.03 (7.99)	1,795.22 (7.50)	1,209.04 (5.05)	1,866.97 (7.80)	1,756.13 (7.34)	1,193.70 (4.99)	1,784.02 (7.82)	1,666.18 (7.30)	1,080.04 (4.74)	1,737.96 (7.62)	1,627.11 (7.13)	1,064.69 (4.67)
Total product cost (¢/lb.) 1/	10,634.00 (44.41)	10,325.72 (43.12)	8,935.12 (37.31)	10,127.97 (42.30)	9,896.27 (41.33)	8,766.46 (36.61)	9,305.85 (40.80)	8,997.36 (39.45)	7,607.08 (33.36)	8,799.82 (38.59)	8,567.93 (37.57)	7,438.41 (32.62)

FOOTNOTES FOR TABLE III

1/ More accurately 10 tons/day (200 tons/mo.) purified esters. Yield of crude esters produced entirely from fresh raw materials is 23,946 pounds per batch. (See "Material Balance", Figure 3 on p. 17.) This amount of crude esters would yield 10 tons of purified esters on the basis of laboratory yields. If free glycerol glucosides and hexane washes enriched with esters, available from purification of a previous batch, are used in a subsequent batch, then only about two thirds as much fresh anhydrous $C_3H_8O_3$ and cornstarch are required per subsequent batch and purification yields are increased so that only 22,805 pounds of crude esters would yield 10 tons of purified esters. Therefore, to convert $/batch to ¢/lb., divide entries in first six columns by 23,946, and entries in last six columns by 22,805. (See pp. 80-83.)

2/ Manufacturing costs for generation of N_2 on the plant site are included in various applicable cost items. If included with raw materials would amount to $27 per batch or 0.11 ¢/lb. crude esters. See Table IV.

3/ 15% of b.

4/ For one shift operation, 75 percent of 6 percent of fixed capital investment. When service facilities and the entire plant are shared for production of other products, then full 6 percent of fixed capital investment or that portion of fixed capital investment attributable to equipment shared.

5/ Depreciated over 18 years for equipment, 45 years for buildings, and 20 years for yard improvements.

6/ 2.5 percent of fixed capital investment.

7/ 1.0 percent of fixed capital investment.

8/ 60 percent of the sum of b, c, and d.

9/ The sum of h, l, and m.

10/ 50 percent of b.

11/ 5 percent of n.

12/ 2 percent of n.

13/ 9 percent of the sum of fixed capital investment and working capital.

Starch handling, storage, and drying in a new or partly depreciated 12-ton batch plant operating the equivalent of only one 8-hour shift daily, 20 days per month, with no sharing of equipment for manufacturing other products, has been estimated to cost 4.21 cents per pound of crude esters, which is equal to 10.99 cents per pound of starch containing 11.5 percent moisture (as received from the manufacturer), or 12.29 cents per pound of starch containing only 1 percent moisture (as fed into the reactor). Adding this handling, storage, and drying cost to the delivered price of cornstarch (11.26 cents per pound) gives the dry starch a value of 22.25 cents per pound on a 11.5 percent moisture basis (equal to 24.89 cents per pound on a 1 percent moisture basis), roughly double its value as received. However, if other products are manufactured in the plant to the extent of 3-shift daily operations (or if esters production would be increased to that extent), starch handling, storage, and drying would decrease to 2.06 cents per pound of crude esters (equal to 5.37 cents per pound of starch containing 11.5 percent moisture or 6.01 cents per pound of starch containing 1 percent moisture).

Manufacturing costs (Table III) include all direct production costs, fixed charges, and plant overhead costs resulting from production of crude glycerol glucoside esters. Included are the following costs:

Direct production costs

Raw materials (anhydrous $C_3H_8O_3$, concentrated H_2SO_4, cornstarch, Na_2CO_3, partially hydrogenated cottonseed oil (I. V. 70), and Na soaps of cottonseed fatty acids.

Operating labor

Direct supervisory and clerical labor

Maintenance and repairs

Operating supplies

Utilities (electricity, water, steam, and natural gas)

Laboratory charges

Fixed charges

Dep.eciation

Property taxes

Insurance

Plant overhead costs

General expenses include various expenditures incurred by company functions other than manufacturing; specifically, administrative, distribution and marketing, research and development, and financing expenses.

Raw materials (Table IV). All raw materials prices include a freight allowance except for (a) the price of partially hydrogenated cottonseed oil (I. V. 70), which could be available at the plant site, or near by, if the esters producer is a refiner, and (b) the price of Na soaps of cottonseed fatty acids, because of their known availability in a geographic area having good potential for locating a glycerol glucoside esters plant. The raw materials are priced on the basis of bulk shipment, with the exception of the small quantities of concentrated H_2SO_4 and Na_2CO_3, which would be supplied on a monthly basis by a local distributor. Negotiated contract prices could be lower than those cited.

RAW MATERIALS SPECIFICATIONS

Anhydrous glycerol ($C_3H_8O_3$). Specs.: nat., refd., U.S.P., C.P., 99 1/2 percent, tanks; or synthetic, U.S.P., 99 1/2 percent, tanks.

Concentrated sulfuric acid (H_2SO_4). Specs.: 66° Baumé or 93 percent by weight, or more concentrated, in 55 gal. drums.

Cornstarch $(C_6H_{10}O_5)_x$. Specs.: refd., powdered, unmodified, pure food starch; approx. 9.5 to 12.5 percent H_2O when purchased, dried to 1 percent H_2O or less before use to expedite reaction of cornstarch and glycerol, minimize the formation of gels, and promote a more complete reaction to produce more monoglu‹osides and less di- and triglucosides; 98 to 99.5 percent thro‹gh 200 mesh sieve; in bulk.

Sodium carbonate (Na_2CO_3). Specs.: food grade, powdered or fine granular, in 100 lb. bags.

Table IV. Crude Glycerol Glucoside Esters of Fatty Acids

RAW MATERIALS COST

Production Rate: 12 tons/day (240 tons/mo.)

Raw Materials	Price, cts./lb. dlvd.	For 12-ton batch of crude esters Lbs.	Dols.	For one pound of crude esters Lbs.	Cts.
Anhydrous $C_3H_8O_3$	49.75				
Added to reactor		13,842			
- Recovered		-10,590			
Net amount used		3,252	1,618	0.136	6.76
Concentrated H_2SO_4 (93%)	5.07	78	4	0.003	0.02
Cornstarch (11.5% H_2O)	11.26	9,177	1,033	0.383	4.31
Na_2CO_3 (a.58.5% Na_2O)	8.95	78	7	0.003	0.03
Partially hydrogenated cottonseed oil (I.V. 70)	30.9	10,810	3,340	0.451	13.95
Na soaps of cottonseed fatty acids	42	1,642	690	0.069	2.88
N_2 gas (generated on site)	0.235 ~~0.0235~~ cts. s.c.f.	11,670 s.c.f. (911 lbs.)	27	0.487 s.c.f. (0.039 lb.)	0.11
All raw materials		25,037 1/	6,719	1.045 1/	28.06

1/ Lbs. of N_2 gas excluded

Partially hydrogenated cottonseed oil (I. V. 70). Specs.: refined, bleached, partially hydrogenated, deodorized cottonseed oil having an I. V. of 70. Contains about 12 percent solids by weight.

Na soaps of refined edible oleic-linoleic oil. Specs.: Can be made from any refined edible oleic-linoleic oil, such as prime, once-refined cottonseed oil or rerefined cottonseed oil (bleaching and hydrogenation not necessary); partially hydrogenated soybean oil; palm oil; peanut oil; but no animal fats. Free of chick edema factor. Made by reacting equivalent amounts of caustic or soda ash and fatty acids, so that the soaps contain no free fatty acids and not more than a fraction of 1 percent free alkali. It is preferable for the soaps to contain no water; however, soaps with up to 5 percent water would be acceptable since the moisture would be removed as steam at the reaction temperature of 190°C. The price cited is for soaps containing 5 percent water. Above 5 percent, the soaps become sticky and difficult to handle. Powder or beads would be satisfactory and are preferred to bars or chips. Chemically pure with the following exceptions: If impurities such as the sterols and sterol esters are present in the edible natural oil from which the soaps are derived, then these impurities are permitted in the soaps; and if made by direct saponification of edible oil, it is all right to leave the glycerol produced in the product. Packed and shipped in returnable 1-ton (74 cu. ft.) epoxy coated steel portable bins. (See "A Complete Equipment List with Specifications and Costs for Producing Crude Glycerol Glucoside Esters, II. Sodium Soaps Receiving, Storage, and Transfer Equipment," p. 29.)

N_2 gas. Specs.: equal to N_2 produced by nitrogen generating system cited in "A Complete Equipment List with Specifications and Costs for Producing Crude Glycerol Glucoside Esters, V. B. Nitrogen Generating System", p. 43. Composition: 20 ppm CO_2, 0.1-0.5 percent CO, 0.1-0.5 percent H_2, 120 ppm (max.) O_2, dew point -80°F at 85 p.s.i.g., remainder N_2 and A. An analysis of costs reveals that self generation is less expensive per s.c.f. of N_2 than purchasing at the anticipated level of consumption and offers potential for even greater savings should N_2 be used in greater quantities.

If the crude esters are purified, glucosides recovered from the crude esters and recycled to subsequent batches enable reduction of raw materials costs to 24.24 cents per pound of crude esters, or almost 4 cents per pound less than shown in Table IV. (Also refer to "3. Material Balance", p. 16, and to Figure 4.)

Operating labor. A study of activities necessary for smooth operation of a 12-ton batch crude glycerol glucoside esters plant has indicated the need for the following personnel. Wage rates used are those currently paid by a national vegetable oil refiner and include a base wage plus a cost of living adjustment paid as stipulated in their labor contracts.

1 reactor operator at $6.00/hr.

1 starch system operator at $6.00/hr.

1 assistant operator (pump man) at $5.90/hr.

1 fork lift operator (half time) at $5.75/hr.

A typical schedule of operations to be followed by production personnel is as follows:

Schedule of Operations

(7 a.m.--3 p.m. shift)

(Note: Schedule of operations for starch drying is reported separately at the end of this schedule.)

Clock time

7:00-9:00 General preparation. Includes: (1) unloading of raw materials such as glycerol, starch, Na soaps, Na_2CO_3, and concentrated H_2SO_4 (also partially hydrogenated cottonseed oil if not captive on site) from railway cars and/or trucks into storage; (2) transporting Na soaps from storage into soaps holding bin; (3) preweighing amounts of concentrated H_2SO_4 and Na_2CO_3 required for processing one batch of crude esters; and (4) servicing recording and control instrumentation.

8:00-9:00 During winter months only, admit steam to coils in glycerol storage tank and glycerol holding tank, start glycerol pumps and mixers in tanks, and heat contents of both tanks to enable pumping from them to the reactor the amount of glycerol required to process one batch of crude esters.

8:30	Start support systems, namely, heat transfer liquid system, nitrogen generating system, steam boiler and cooling tower. (During winter months when steam is needed in glycerol tank coils to prevent freezing of or to thaw glycerol, steam boiler would be started at the beginning of the shift.)
8:45 ~~9:00~~	Begin reactor cycle. Start pumping glycerol into the reactor. Start reactor mixer. Admit N_2 to reactor, and heat transfer liquid to reactor jacket. Start reactor pump. Heat glycerol to 100°C. (212°F.) with the assistance of mixing and circulation. Add concentrated H_2SO_4 slowly and mix thoroughly with the glycerol. Heat mixture to 125°C. (257°F.). Stop reactor pump.
9:25- 9:28	3 minute interval before addition of starch. (Not shown in Figure)
9:28- 9:48	Admit starch from dry starch bin through solids flow transmitter into the reactor, with vigorous mixing, maintaining temperature at 125°C.
9:48-10:28	Reaction between glycerol and starch (transglycosylation) is continued at 125°C.
10:28-10:33	Add Na_2CO_3 to reaction mixture. Start live bottom of soaps holding bin.
10:33-10:38	Start Na soaps feeder and deliver soaps from holding bin to reactor. Simultaneously pump partially hydrogenated oil from the holding tank to the reactor. Temperature of mixture drops to 91.4°C. (196.5°F.).
10:38-11:18	Admit heat transfer liquid to jacket of auxiliary heat exchanger and start reactor pump. Reaction mixture is heated to 190°C. (374°F.) while circulating reaction mixture through the auxiliary heat exchanger, heat being supplied by the heat transfer liquid in the jackets of both the reactor and the auxiliary heat exchanger. Interesterification begins.
11:18-11:38	Interesterification continues at 190°C. with stirring of mixture.
11:38-12:58	Shut off N_2 to reactor. Interesterification continues. Cooling water is admitted to glycerol condenser and aftercooler as well as to steam ejector surface intercondensers and aftercondenser. Steam ejector is brought on stream and glycerol is distilled at 190°C. while pressure is gradually reduced to 2-3 mm. Hg absolute.

12:58- 1:28 Shut down heat transfer liquid system. Maintain vacuum on reactor, and remove traces of glycerol from crude esters by sparging with steam.

1:28- 1:48 Start crude esters pump. Pump crude esters from the reactor to the crude esters storage tank.

1:48- 3:00 If product shipment is scheduled for a particular workday, admit steam to the coil in the crude esters storage tank, and with the aid of the mixer in the tank as well as circulation by the crude esters pump, heat crude esters to enable pumping them more readily from the crude esters storage tank to a tank car for shipment. Shut down steam boiler. (If product shipment is not scheduled, steam boiler can be shut down at 2:20 p.m. on completion of starch drying.) Clean up.

APPENDIX TO SCHEDULE OF OPERATIONS

(7 a.m.--3 p.m. shift)

Starch Drying

Clock time

10:00 Begin preheating dryer with steam and air.

10:30 Admit N_2 to dry starch bin. Begin starch drying. Dry starch begins collecting in bin immediately.

2:20 Starch drying completed. Shut down N_2 generator, with enough N_2 in receiver to supply N_2 to dry starch bin until contents are discharged to reactor the next day at 9:28-9:48 a.m. Shut down cooling tower.

Direct supervisory and clerical labor cost has been estimated on the basis of 15 percent of operating labor.

Maintenance and repair cost includes labor, materials, and supervision. For one-shift operation, which is an operating rate of only 33 percent of capacity, annual maintenance and repair cost has been estimated on the basis of 75 percent of that at 100 percent capacity. Since this process is considered to be at most an average and uncomplicated process with relatively normal operating conditions, this would amount to 75 percent of 6 percent of fixed capital investment, or 4.5 percent. For 3-shift operation, a full 6 percent of fixed capital investment was used.

Table V. Crude Glycerol Glucoside Esters of Fatty Acids

Utilities Cost

Production Rate: 12 tons/day (240 tons/mo.)

		For 12-ton batch of crude esters		For one pound of crude esters
Utility	Unit cost of utility	Quantity	Cost	Cost
Electricity	1.97-3.55¢/kw-hr	768.7 kw-hr	\$15.17-\$27.30	0.06¢-0.11¢
Water (Tower make-up)	85-95¢/M gals.	4.2 M gals.	\$3.58-\$3.97	0.02¢
Steam (250 p.s.i.g.)	\$2.20/M lbs.	13 M lbs.	\$28.55	0.12¢
Natural gas	\$1.44/M s.c.f.	22.6 M s.c.f.	\$32.49	0.14¢
All			\$79.79-\$92.31	0.34¢-0.39¢

Operating supplies cost has been estimated on the basis of 15 percent of maintenance and repairs, and includes such items as instrumentation charts, lubricants, make-up amounts of heat transfer liquid, and janitor supplies.

Utilities cost (which includes electricity, water, steam at 250 p.s.i.g., and natural gas) is summarized in Table V for the 12-ton batch plant when producing crude esters entirely from fresh raw materials. Consumption of utilities is less when producing crude esters from both fresh raw materials and recovered glycerol glucosides (refer to Table III), because for the same production of purified product there is less starch to dry and less glycerol to be distilled from the reaction mixture during interesterification. The utilities rates used are largely applicable in areas of southeast Louisiana, and they fall within ranges cited in the literature.

Electricity. Consumption of electricity by the various equipment units is itemized in "5. A Complete Equipment List with Specifications and Costs for Producing Crude Glycerol Glucoside Esters, V. Service Facilities, E. Offsite Electric Distribution System," p. 48. Peak demand is 282.5 HP or 210.6 kw., which occurs during addition of Na soaps and partially hydrogenated cottonseed oil to the reactor. This would occur between 10:33 and 10:38 a.m. for the 7 a.m.-3 p.m. shift. (Refer to "Schedule of Operations," p. 89). Although this peak demand does not last the 15 minutes required for billing, it was used in the calculations, as a factor of safety.

Louisiana Power and Light Company's Large General Service Schedule LGS-6 and 5A, January 1, 1973, with fuel adjustment dated July 1974, shown as follows, and available in many southeast Louisiana communities including Gretna, was used in this cost study. (Refer to "National Electric Rate Book, Louisiana," 1974, Schedule No. 36 and Fuel Adjustments Reported by Utilities, Federal Power Commission, Washington, D.C., 20425, pp. 5 and 20.)

Application of Louisiana Power and Light Company Large General Service Schedule LGS-6 and 5A as given on the next page to the quantity of electricity consumed is equivalent to a cost of 1.97 cents to 3.55 cents per kw-hr when producing crude esters entirely from fresh raw materials; the lower cost on the basis of operation of a new or partly or fully depreciated plant, in which the entire plant is shared for other production to the extent that total plant operation becomes 3 shifts daily; the higher cost on the

Louisiana Power and Light Company

Large General Service

Desig: LGS-6 and 5A January 1, 1973

Rate:

Demand Charge

$144.00 for first 60 kw. demand or less

1.40 per kw. for next 140 kw. demand

1.25 per kw. for all additional kw. demand

Energy Charge

1.30¢ per kw-hr	first 5,000 kw-hr
1.00¢ per kw-hr	next 25,000 kw-hr
0.75¢ per kw-hr	additional kw-hr up to 40,000 kw-hr or up to 400 kw-hr per kw. demand, whichever is greater
0.50¢ per kw-hr	all additional kw-hr

Fuel adjust: 0.315¢/kw-hr

basis of 1-shift daily production of esters with no sharing of equipment for other production. When producing crude esters from both fresh raw materials and recovered glycerol glucosides from purification of a previous batch, the Louisiana Power and Light Company schedule is equivalent to a cost of 2.03 to 3.78 cents per kw-hr respectively, representing a slight rise in unit cost in comparison with production of crude esters entirely from fresh raw materials because of lower total consumption of electricity.

Water is used for service facilities only (i.e., for producing steam and for cooling tower make-up), there being no process water as such in the production of crude esters. However, should purification of crude esters be undertaken, process water would become necessary as described in the purification procedure outlined in "3. Material Balance," p. 16. Water used for steam is included in the cost of steam. (Refer to "Steam" immediately following this section on water costs.) Water is added as make-up water for the cooling tower at the rate of 4,200 gallons per 12-ton batch of crude esters. (Refer to "Cooling Tower" under "5. A complete Equipment List and Specifications and Costs for Producing Crude Glycerol Glucoside Esters, V. Service Facilities," p. 39.)

Water rates of the Sewerage and Water Board of New Orleans, reflecting a recently proposed increase, were used in calculating water cost. The water rates include water, sewerage, and quality control as follows:

Sewerage and Water Board of New Orleans

Proposed Monthly Rates for General Service

WATER RATES

Service Charges

Meter Size Inches	Amount Dols.
5/8	1.35
3/4	1.65
1	2.25
1-1/2	3.50
2	7.50
3	16.00
4	28.00
6	55.00
8	80.00
10	110.00
12	130.00
16	175.00

Water Charges

Quantity Gals.	Charge per 1000 gallons Dols.
First 20,000	0.61
Next 980,000	0.45
All over 1,000,000	0.35

SEWERAGE

Service Charges

Meter Size Inches	Amount Dols.
5/8	0.95
3/4	1.00
1	1.50
1-1/2	2.00
2	4.00
3	5.50
4	7.00
6	13.00
8	22.00
10	33.00
12	43.00
16	70.00

Quantity Charges Gals.	Charge per 1000 gallons Dols.
First 20,000	0.49
Next 1,980,000	0.35
All over 2,000,000	0.26

QUALITY CONTROL

Quantity Charges Gals.	Charge per 1000 gallons Dols.
First 20,000	0.010
All over 20,000	0.007

Application of the Sewerage and Water Board of New Orleans proposed schedule as given above to the quantity of water consumed is equivalent to a cost of 85 cents to 95 cents per thousand gallons; the lower cost on the basis of operation of a new, or partly or fully depreciated plant, in which the entire plant is shared for other production to the extent that total plant operation becomes 3 shifts daily; the higher cost on the basis of 1-shift daily production of esters with no sharing of equipment for other production.

Steam at 250 p.s.i.g. pressure is used to dry cornstarch; to sparge traces of glycerol from crude esters in the reactor on completion of vacuum distillation of glycerol; to operate the steam jet ejector; and to heat bulk quantities of glycerol and crude esters as required; as listed in "5. A Complete Equipment List with Specifications and Costs for Producing Crude Glycerol Glucoside Esters, V. Service Facilities, C. Steam Boiler and Accessories", p. 45. A steam rate of \$2.20 per thousand pounds was used in calculating steam cost. This rate was selected as a fair compromise of steam rates published in recent chemical engineering cost literature.

Natural gas is used to fire the steam boiler and thermal liquid heater, and to produce inert gas in the nitrogen generating system. Consumption of natural gas for a 12-ton batch of crude esters is as follows:

	Standard cu. ft. per batch
Thermal liquid heater	20,288
Nitrogen generator	2,272
Steam boiler	15,236
	37,796

The cost of natural gas for firing the steam boiler is included in the steam cost reported in the previous section. Therefore, consumption of only 22.6 thousand standard cubic feet per batch was used in estimating natural gas cost. The natural gas rate charged a large vegetable oil refiner in this area by the Louisiana Gas Service Company was used in calculating natural gas cost, namely, \$1.44 per thousand standard cubic feet.

Laboratory charges cover the cost of laboratory tests for control of operations and for product quality control. Testing for reaction of starch and glycerol can be done in several ways. The visual test is the most rapid. If reaction occurs, a honey-like material

is produced; otherwise a gel is formed. A very rapid test involves adding a small sample of reaction mixture to cold water. If the reaction has gone to completion, the sample will dissolve in the water. If the reaction is incomplete, the unreacted starch present remains undissolved. Other more time consuming tests include refractive index and thin layer chromatographic analysis.

The completeness of interesterification can be determined by thin layer chromatographic analysis, which is the method that has been used in research on glycerol glucoside esters at the Southern Regional Research Center.

Laboratory charges were taken as 15 percent of operating labor.

Depreciation was calculated on the basis of depreciable lives of 18 years for equipment, 20 years for yard improvements, and 45 years for buildings, as specified in "Depreciation Guidelines and Rules", U.S. Treasury Department, Internal Revenue Service, Publication No. 456 (7-62), July 1962, 56 pages.

Property taxes are completely dependent upon the locality in which the plant is located. In general, plants located in cities pay higher taxes than those in less populated regions. In the absence of specific data, an annual value equivalent to 2.5 percent of fixed capital investment was used to approximate property taxes. This annual value is close to average local and state property taxes for 26 states reported in "The Effect of State and Local Taxes on Profits in Food Processing," by W. Smith Greig, Ag. Economics Report No. 145, Dept. of Ag. Economics, Michigan State University, pp. 13, 16 and 20 (Table IV), August, 1969. Average local and state property taxes for 26 states were found to be $23.16/$1000 market value for land, $23.21/$1000 for buildings, $20.60/$1000 for equipment and $16.93/$1000 for inventories.

Insurance was taken on an annual basis to be equivalent to 1 percent of fixed capital investment.

Plant overhead costs were calculated on the basis of 60 percent of the sum of operating labor plus direct supervisory and clerical labor plus maintenance and repairs. Plant overhead includes the many expenses indirectly related to the production operation, as follows:

payroll overhead including employee benefits (35-45% of operating labor)

general plant maintenance and overhead

medical services

safety and protection

lunchroom

recreation

employment offices

shops and salvage

lighting and other utilities

interplant communications and transportation

general engineering and drafting

purchasing

receiving and shipping facilities

packaging

storage facilities (other than process storage)

janitor and similar services

<u>Administrative expenses</u> include top-management or administrative activities that cannot be charged directly to manufacturing costs. They are salaries and wages for administrators, secretaries, accountants, stenographers, typists, and similar workers; costs for office supplies and equipment, outside communications, administrative buildings, and other overhead items related to administrative activities. Administrative expenses were calculated on the basis of 50 percent of operating labor.

<u>Distribution and marketing expenses</u> include salaries, wages, supplies, and other expenses for sales offices; salaries, commissions, and traveling expenses for salesman; shipping expenses; cost of containers; advertising expenses; and technical sales service. These expenses were taken as only 5 percent of total manufacturing cost because the product would be sold mostly in large volume to other manufacturers (food processors), and although the product is new, presumably it would be distributed and marketed along with an established line of products of a manufacturer, for which means and channels of distribution and a sales organization already exist.

Research and development expenses include salaries and wages for all personnel directly connected with research and development work, fixed and operating expenses for all machinery and equipment involved, costs for materials and supplies, direct overhead expenses and miscellaneous costs. They were calculated as an amount equivalent to 2 percent of total manufacturing costs.

Financing expenses have been calculated as an amount equivalent to 9 percent of the sum of total plant investment and working capital. Working capital was calculated using the following equation:

$$\text{Working capital} = r_m(m + 4M + 0.5MQ)$$

where r_m = monthly production rate

m = raw-material cost per unit of production

Q = production cycle, months

M = manufacturing cost per unit of production

From the above it is seen that working capital as calculated includes a 1-month supply of raw materials valued at delivered prices; product inventory equal to 1 month's production valued at manufacturing cost; extended credit estimated at 1 month's production at the sales value or at twice the manufacturing cost; available cash for payment of wages and for services and materials, approximated as 1 month's manufacturing expense; and in-process inventory estimated as one half the manufacturing cost occurring during a period equivalent to the total holdup time required for processing.

8. PROFITABILITY

(Refer to Table VI in this section)

Summary: Annual profits, annual rates of return on investment, and payout times over a range of selling prices are given in Table VI for the production of crude glycerol glucoside esters in 12-ton batches in new or partly depreciated plants using fresh raw materials, with and without sharing of production equipment and service facilities with other products.

Rate of return on investment (Table VI). If there is no sharing of the use of esters production equipment and service facilities with other products (the equivalent of 1-shift daily operations), selling of crude esters at a price of 51 cents per pound (includes 6.59 cents per pound profit) yields an annual rate of return on investment of 11.44 percent before income taxes and 6.36 percent after income taxes. If production equipment and service facilities are shared (the equivalent of 3-shift daily operations), selling of crude esters at a price of 41 cents per pound (includes 3.69 cents per pound profit) yields an annual rate of return on investment of 13.38 percent before income taxes and 7.81 percent after income taxes.

A rate of return on investment before income taxes of 50 percent (as required by some industrial concerns before considering investing capital in projects) can be realized by increasing selling price to 51.1 cents per pound if equipment and facilities are shared and to 73.2 cents per pound if equipment and facilities are used only for glycerol glucoside esters production.

Payout period (Table VI). At prices of 51 cents per pound when there is no sharing of equipment and facilities, and of 41 cents per pound when there is sharing, payout period based on gross profit (before income taxes) is 5.0 years and 3.3 years, respectively. Payout period based on profit after income taxes is 7.7 years and 5.1 years, respectively.

At crude esters prices of 73.2 cents per pound when there is no sharing of equipment and facilities, and of 51.1 cents per pound when there is sharing (equivalent to 50 percent return on investment before income taxes), payout period based on gross profit (before income taxes) is 1.4 years and 1.0 years, respectively. Payout period based on profit after income taxes is 2.5 and 1.8 years, respectively.

Table VI Profitability of producing crude glycerol glucoside esters

Production Rate 12 tons/day (240 tons/mo.)

	No sharing of production equipment and service facilities with other products								Sharing of production equipment and service facilities with other products					
Selling price, ¢/lb.	50	51	55	60	65	70	73.21	75	40	41	45	50	51.10	55
Cost 1/, ¢/lb.	44.41	44.41	44.41	44.41	44.41	44.41	44.41	44.41	37.31	37.31	37.31	37.31	37.31	37.31
Profit before taxes, ¢/lb.	5.59	6.59	10.59	15.59	20.59	25.59	28.80	30.59	2.69	3.69	7.69	12.69	13.79	17.69
Annual profit, dols.														
Before taxes	321,260	378,730	608,612	895,964	1,183,316	1,470,668	1,655,284	1,758,020	154.595	212,066	441,947	729,299	792,475	1,016,651
After taxes 2/	180,555	210,440	329,978	479,401	628,824	778,247	874,248	927,670	93,890	123,774	243,312	392,735	425,587	542,159
Annual rate of return on investment 3/, %														
Before taxes	9.70	11.44	18.38	27.06	35.74	44.42	50.00	53.10	9.75	13.38	27.88	46.01	50.00	63.74
After taxes	5.45	6.36	9.97	14.48	18.99	23.51	26.41	28.02	5.92	7.81	15.35	24.78	26.85	34.21
Payout period 4/, yrs.														
Before taxes	5.71	5.04	3.43	2.45	1.91	1.56	1.40	1.32	4.30	3.31	1.72	1.07	0.99	0.78
After taxes 2/	8.47	7.68	5.60	4.18	3.33	2.77	2.50	2.37	6.30	5.13	2.94	1.91	1.78	1.52

FOOTNOTES FOR TABLE VI

1/ Using fresh raw materials in new plant.

2/ Taxes were calculated as follows: The first $25,000 at a 20% normal tax rate, all taxable income over $25,000 at 22% normal tax rate, and all taxable income in excess of $50,000 at a 26% surtax rate. (Ref. Commerce Clearing House Manual, Code Sec. 11, par. 1260 ff, pp. 809-812, February 6, 1976.)

3/ Annual rate of return on investment,

$$\% = \frac{\text{profit before or after income taxes}}{\text{fixed capital investment + working capital}} \times 100$$

4/ Payout period, years
(no interest charge)

$$= \frac{\text{depreciable fixed capital investment}}{\text{avg. profit before or after taxes/yr. + avg. depreciation/yr.}}$$

Profitability of 4-ton batches. Rate of return on investment of a new or partly depreciated plant producing sixty 4-ton batches of crude esters monthly (the equivalent of operating three 8-hr. shifts daily, 20 days/mo.) for sale at a price of 51 cents per pound (includes 5.76 cents per pound profit) would be 12.02 percent before income taxes and 6.74 percent after income taxes. A rate of return on investment of 50 percent can be realized by increasing selling price to 69.2 cents per pound. At a price of 51 cents per pound, payout period based on gross profit (before income taxes) is 4.6 years, and payout period based on profit after income taxes is 7.0 years. At a price of 69.2 cents per pound (equivalent to 50 percent return on investment before income taxes), payout period based on gross profit (before income taxes) is 1.3 years, and payout period based on profit after income taxes is 2.3 years.

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